Final - Bitterroot Watershed Total Maximum Daily Loads and Water Quality Improvement Plan

December 2014

Steve Bullock, Governor
Tracy Stone-Manning, Director DEQ

Document Number C05-TMDL-04aF

Prepared by:
Water Quality Planning Bureau
Watershed Management Section

Contributors:
Water Quality Planning Bureau
Watershed Management Section
Mindy McCarthy, Nutrients Project Manager
Christian Schmidt, Previous Nutrients Project Manager
Jordan Tollefson, Project Coordinator and Temperature Project Manager

Information Management and Technical Services Section
Kyle Flynn, Project Modeler
Mike Van Liew, Previous Modeler

U.S. Environmental Protection Agency
Peter Brumm, Metals Project Manager

Montana Department of Environmental Quality
Water Quality Planning Bureau
1520 E. Sixth Avenue
P.O. Box 200901
Helena, MT 59620-0901

Suggested citation: Montana DEQ and U.S. EPA Region 8. 2014. Bitterroot Watershed Total Maximum Daily Loads and Water Quality Improvement Plan. Helena, MT: Montana Dept. of Environmental Quality.

ACKNOWLEDGEMENTS

DEQ would like to acknowledge multiple entities for their contributions in the development of the TMDLs contained in this document. This project was a joint effort with the Montana Office of the U.S. Environmental Protection Agency (EPA). DEQ would like to thank the EPA staff that contributed to the completion of this project. Peter Brumm was a vital member of this project, serving as the project manager for the metals TMDLs in **Section 6.0** and authoring **Section 2.0**, the Bitterroot Watershed Project Area Description, as well as creating all maps contained in **Appendix A**.

DEQ would also like to thank Jessica Clarke with our Monitoring and Assessment Section who conducted water quality monitoring in support of the metals and nutrients TMDLs; and Carrie Greeley, an administrative assistant, for her time and effort formatting this document.

A consulting firm, Tetra Tech, Inc., provided support with temperature field data collection, data analysis, and modeling for Mill Creek, and authored **Section 7.0** in the document, as well as authored **Attachment A**, *Modeling Water Temperature in Mill Creek.*

DEQ would also like to thank the Bitterroot Water Forum and Gil Gale from the Bitterroot National Forest for their input and assistance throughout development of these TMDLs. Draft versions of source assessment reports and this document were sent to stakeholders for review and input. The involvement of all reviewers led to improvements in this document and is greatly appreciated.

TABLE OF CONTENTS

APPENDICES

ATTACHMENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYM LIST

Acronym	Definition
AFDM	Ash Free Dry Mass
AMB	Abandoned Mine Bureau
AML	Abandoned Mine Lands
ARM	Administrative Rules of Montana
AU	Assessment Unit
AUM	Animal Unit Months
BLM	Bureau of Land Management (Federal)
BMP	Best Management Practices
BRID	Bitter Root Irrigation District
CALA	Controlled Allocation of Liability Act
CECRA	[Montana] Comprehensive Environmental Cleanup and Responsibility Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CWA	Clean Water Act
DEQ	Department of Environmental Quality (Montana)
DNRC	Department of Natural Resources & Conservation (Montana)
DOI	Department of the Interior (federal)
DQA	Data Quality Analysis
DQO	Data Quality Objectives
EMAP	Environmental Monitoring and Assessment Program
EPA	Environmental Protection Agency (U.S.)
EQIP	Environmental Quality Incentives Program
FWP	Fish, Wildlife & Parks (Montana)
GIS	Geographic Information System
HBI	Hilsenhoff Biotic Index
HCP	Habitat Conservation Plans
HDPE	high-density polyethylene
HUC	Hydrologic Unit Code
INFISH	Inland Native Fish Strategy
IR	Integrated Report
LA	Load Allocation
LA_{NAT}	Load Allocation to Natural Background Sources
LA_{NB}	Load Allocation to Natural Background Sources
LA_{NPS}	Load Allocation to Nonpoint Sources
LA_{UW}	Load Allocation to the Watershed Upstream of the Impaired Reach
MBMG	Montana Bureau of Mines and Geology
MCA	Montana Code Annotated
MFISH	Montana Fisheries Information System
MGWPCS	Montana Ground Water Pollution Control System
MOS	Margin of Safety
MPDES	Montana Pollutant Discharge Elimination System
MSDI	Montana Spatial Data Infrastructure
MSU	Montana State University
NOAA	National Oceanographic and Atmospheric Administration

Acronym	Definition
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
PEL	Probable Effects Levels
QAPP	Quality Assurance Project Plan
RAWS	Remote Automatic Weather Station
RIT/RDG	Resource Indemnity Trust / Reclamation and Development Grants Program
RM	River Mile
SMCRA	Surface Mining Control & Reclamation Act
SMZ	Streamside Management Zone
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TPA	TMDL Planning Area
TSWQC	Tri-State Water Quality Council
US	United States
USDA	United States Department of Agriculture
USFS	United States Forest Service
USFWS	US Fish and Wildlife Service
USGS	United States Geological Survey
UUILT	Ultimate Upper Incipient Lethal Temperature
WLA	Wasteload Allocation
WRP	Watershed Restoration Plan
WWTP	Wastewater Treatment Plant

DOCUMENT SUMMARY

This document presents a total maximum daily load (TMDL) and water quality improvement plan for 11 impaired waterbodies in the Bitterroot River watershed (see **Figure A-2** found in **Appendix A**).

The Montana Department of Environmental Quality (DEQ) develops TMDLs and submits them to the U.S. Environmental Protection Agency (EPA) for approval. The Montana Water Quality Act requires DEQ to develop TMDLs for streams and lakes that do not meet, or are not expected to meet, Montana water quality standards. A TMDL is the maximum amount of a pollutant a waterbody can receive and still meet water quality standards. TMDLs provide an approach to improve water quality so that streams and lakes can support and maintain their state-designated beneficial uses.

The project area encompasses approximately 2,857 square miles in southwestern Montana as shown in **Figure A-1**. Most of the project area resides in Ravalli County, with the northern portion residing in Missoula County. The project area is bounded by the Bitterroot Mountains to west and by the Sapphire Mountains to the east. All surface water drains to the northward flowing Bitterroot River and leaves the project area near Missoula. The Montana Department of Environmental Quality (DEQ) divides the state into TMDL Planning Areas (TPAs) for workload purposes based on topographic drainage boundaries and other considerations. In some instances, when TMDLs are developed, these planning areas are realigned into project areas. In this case, the Upper Lolo TPA, Bitterroot TPA, and Bitterroot Headwaters TPA were combined to create the Bitterroot Watershed Project Area (see **Figure A-2**).

DEQ determined that 11 waterbodies within the Bitterroot watershed do not meet the applicable water quality standards. The scope of the TMDLs in this document addresses problems with nutrients, metals, and temperature (see **Table DS-1**). A total 18 TMDLs were developed for 19 pollutant impairment listings, with the NO_3+NO_2 impairment on Threemile Creek being addressed by a total nitrogen TMDL.

Nutrients were listed as impairing aquatic life and primary contact recreation in Ambrose Creek, Bass Creek, Lick Creek, Muddy Spring Creek, North Burnt Fork Creek, North Fork Rye Creek, Rye Creek, Sweathouse Creek, and Threemile Creek. Excess nitrogen in the form of dissolved ammonia (which is typically associated with wastewater) can be toxic to fish and other aquatic life. Excess nitrogen in the form of nitrate in drinking water can inhibit normal hemoglobin function in infants. In addition, excess nitrogen and phosphorus from human sources can cause excess algal growth, which in turn depletes the supply of dissolved oxygen, killing fish and other aquatic life. Excess nutrient concentrations in surface water create blue-green algae blooms (Priscu, 1987), which can produce toxins lethal to aquatic life, wildlife, livestock, and humans. Aside from the toxicity effects, nuisance algae can shift the structure of macroinvertebrate communities, which may also negatively affect the fish that feed on macroinvertebrates (U.S. Environmental Protection Agency, 2010). Additionally, changes in water clarity, fish communities, and aesthetics can harm recreational uses, such as fishing, swimming, and boating (Suplee et al., 2009). Nuisance algae can also increase the cost of treating drinking water or pose health risks if ingested in drinking water (World Health Organization, 2003b). Water quality restoration goals for nutrients were based on the numeric nutrient criteria in Circular DEQ-12A. DEQ believes that once these water quality goals are met, all water uses currently affected by nutrients will be restored.

Nutrient loads are quantified for natural background conditions and for human caused sources (agriculture, silviculture, and septic). The Bitterroot watershed Total Nitrogen TMDLs indicate that reductions in Total Nitrogen (TN) loads ranging from 17%-60% will satisfy the water quality restoration goals, Total Phosphorus TMDLs indicate that reductions in total phosphorus (TP) loads ranging from 19%-80% will satisfy the water quality restoration goals, and Nitrate/Nitrite TMDLs indicate that reductions in $NO_3 + NO_2$ loads ranging from 19%-80% will satisfy the water quality restoration goals. Recommended strategies for achieving the nutrient reduction goals are also presented in this plan.

Metals were listed as impairing aquatic life Lick Creek and the Bitterroot River. Within aquatic ecosystems, metals can have a toxic, carcinogenic, or bioconcentrating effect on biota. Likewise, humans and wildlife can suffer acute and chronic effects from consuming water or fish with elevated metals concentrations. Targets for metals-related impairments in the Bitterroot TMDL Project Area include both water chemistry targets and sediment chemistry targets. The human health and aquatic life criteria defined in DEQ Circular DEQ-7 (Montana Department of Environmental Quality, 2012) are used directly as water chemistry targets for these TMDLs. Sediment chemistry targets are adopted from numeric screening values for metals in freshwater sediment established by the National Oceanographic and Atmospheric Administration (NOAA). DEQ believes that once these water quality goals are met, all water uses currently affected by metals will be restored.

Metals loads are quantified for natural background conditions, for human caused nonpoint sources, and for two point sources (the Lolo wastewater treatment plant, and the Missoula MS4). The Bitterroot River lead TMDLs indicate that reductions in lead loads of 77% will satisfy the water quality restoration goals. The Lick Creek aluminum TMDLs indicate that reductions in aluminum ranging from 71% at low flow conditions to 88% at high flow conditions will satisfy the water quality restoration goals. Recommended strategies for achieving the metals reduction goals are also presented in this plan.

Temperature was listed as impairing aquatic life in Mill Creek. Warmer temperatures can negatively affect aquatic life that depends upon cool water for survival. Coldwater fish species are more stressed in warmer water temperatures, which increases metabolism and reduces the amount of available oxygen in the water. Coldwater fish and other aquatic life may feed less frequently and use more energy to survive in thermal conditions above their tolerance range, which can result in fish kills. Also, elevated temperatures can boost the ability of non-native fish to outcompete native fish if the latter are less able to adapt to warmer water conditions (Bear et al., 2007). The target for allowable human-caused temperature change links directly to the numeric portion of Montana's temperature standard for B-1 streams [ARM 17.30.623(e)]: When the naturally occurring temperature is less than 66^{o}F, the maximum allowable increase is 1^{o}F. Within the naturally occurring temperature range of 66–66.5^{o}F, the allowable increase cannot exceed 67^{o}F. If the naturally occurring temperature is greater than 66.5^{o}F, the maximum allowable increase is 0.5^{o}F. DEQ believes that once these water quality goals are met, all water uses currently affected by temperature will be restored.

Temperature loads for Mill Creek are quantified based on data collected and temperature modeling results, which represents the application of all reasonable land, soil, and water conservation practices. The Mill Creek temperature TMDLs indicate that reductions ranging from 2.6% at the mouth to 16% at River Mile (RM) 4.6 will satisfy the water quality restoration goals. Recommended strategies for achieving the temperature reduction goals are also presented in this plan.

Implementation of most water quality improvement measures described in this plan is based on voluntary actions of watershed stakeholders. Ideally, local watershed groups and/or other watershed stakeholders will use this TMDL document, and associated information, as a tool to guide local water quality improvement activities. Such activities can be documented within a watershed restoration plan consistent with DEQ and EPA recommendations.

A flexible approach to most nonpoint source TMDL implementation activities may be necessary as more knowledge is gained through implementation and future monitoring. The plan includes a monitoring strategy designed to track progress in meeting TMDL objectives and goals and to help refine the plan during its implementation.

Although most water quality improvement measures are based on voluntary measures, federal law specifies permit requirements developed to protect narrative water quality criterion, a numeric water quality criterion, or both, to be consistent with the assumptions and requirements of wasteload allocations (WLAs) on streams were TMDLs have been developed and approved by EPA. The Bitterroot Watershed Project Area has permitted dischargers requiring the incorporation of WLAs into permit conditions on the Bitterroot River.

Table DS-1. List of Impaired Waterbodies and their Impaired Uses in the Bitterroot Watershed Project Area with Completed Nutrient, Metals, and Temperature TMDLs Contained in this Document

Waterbody & Location Description	TMDL Prepared	TMDL Pollutant Category	Impaired Use(s)*
Ambrose Creek, headwaters to mouth (Threemile Creek)	Nitrogen (Total)	Nutrients	Aquatic Life Primary Contact Recreation
	Phosphorus (Total)	Nutrients	Aquatic Life Primary Contact Recreation
Bass Creek, Selway-Bitterroot Wilderness boundary to mouth (un-named channel of Bitterroot River)	Nitrogen (Total)	Nutrients	Aquatic Life Primary Contact Recreation
	Phosphorus (Total)	Nutrients	Aquatic Life Primary Contact Recreation
Bitterroot River, Eightmile Creek to mouth (Clark Fork River)	Lead	Metals	Aquatic Life
Lick Creek, headwaters to mouth (Bitterroot River)	Aluminum	Metals	Aquatic Life
	Phosphorus (Total)	Nutrients	Aquatic Life Primary Contact Recreation
Mill Creek, Selway-Bitterroot Wilderness boundary to the mouth (Fred Burr Creek)	Temperature, water	Temperature	Aquatic Life
Muddy Spring Creek, headwaters to mouth (Gold Creek)	Nitrate/Nitrite (Nitrate + Nitrite as N)	Nutrients	Aquatic Life Primary Contact Recreation
North Burnt Fork Creek, confluence with South Burnt Fork Creek to Mouth (Bitterroot River)	Nitrogen (Total)	Nutrients	Aquatic Life Primary Contact Recreation
	Phosphorus (Total)	Nutrients	Aquatic Life Primary Contact Recreation
North Fork Rye Creek, headwaters to mouth (Rye Creek-Bitterroot River, South of Darby)	Nitrogen (Total)	Nutrients	Aquatic Life Primary Contact Recreation
	Phosphorus (Total)	Nutrients	Aquatic Life Primary Contact Recreation

Table DS-1. List of Impaired Waterbodies and their Impaired Uses in the Bitterroot Watershed Project Area with Completed Nutrient, Metals, and Temperature TMDLs Contained in this Document

Waterbody & Location Description	TMDL Prepared	TMDL Pollutant Category	Impaired Use(s)*
Rye Creek, North Fork to mouth (Bitterroot River)	Nitrogen (Total)	Nutrients	Aquatic Life Primary Contact Recreation
	Phosphorus (Total)	Nutrients	Aquatic Life Primary Contact Recreation
Sweathouse Creek, headwaters to mouth (Bitterroot River)	Phosphorus (Total)	Nutrients	Aquatic Life Primary Contact Recreation
Threemile Creek, headwaters to mouth (Bitterroot River)	Nitrogen (Total)	Nutrients	Aquatic Life Primary Contact Recreation
	Phosphorus (Total)	Nutrients	Aquatic Life Primary Contact Recreation

*Impaired uses given in this table are based on updated assessment results and may not match the "2014 Water Quality Integrated Report."

1.0 Project Overview

This document presents an analysis of water quality information and establishes total maximum daily loads (TMDLs) for nutrient, temperature, and metals problems in the Bitterroot TMDL Planning Area (TPA). This document also presents a general framework for resolving these problems. **Figure A-2**, found in **Appendix A**, shows a map of waterbodies in the Bitterroot Watershed Project Area with nutrient, temperature, and metals pollutant listings.

1.1 Why We Write TMDLs

In 1972, the U.S. Congress passed the Water Pollution Control Act, more commonly known as the Clean Water Act (CWA). The CWA's goal is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The CWA requires each state to designate uses of their waters and to develop water quality standards to protect those uses.

Montana's water quality designated use classification system includes the following:

- fish and aquatic life
- wildlife
- recreation
- agriculture
- industry
- drinking water

Each waterbody in Montana has a set of designated uses from the list above. Montana has established water quality standards to protect these uses, and a waterbody that does not meet one or more standards is called an impaired water. Each state must monitor their waters to track if they are supporting their designated uses, and every two years the Montana Department of Environmental Quality (DEQ) prepares a Water Quality Integrated Report (IR) which lists all impaired waterbodies and their identified impairment causes. Impairment causes fall within two main categories: pollutant and non-pollutant.

Montana's biennial IR identifies all the state's impaired waterbody segments. The 303(d) list portion of the IR includes all of those waterbody segments impaired by a pollutant, which require a TMDL, whereas TMDLs are not required for non-pollutant causes of impairments. **Table A-1** in **Appendix A** identifies all impaired waters for the Bitterroot Watershed Project Area from Montana's 2014 303(d) List, and includes non-pollutant impairment causes included in Montana's "2014 Water Quality Integrated Report" (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2014). **Table A-1** provides the current status of each impairment cause, identifying whether it has been addressed by TMDL development.

Both Montana state law (Section 75-5-701 of the Montana Water Quality Act) and section 303(d) of the federal CWA require the development of total maximum daily loads for all impaired waterbodies when water quality is impaired by a pollutant. A TMDL is the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards.

Developing TMDLs and water quality improvement strategies includes the following components, which are further defined in **Section 4.0**:

- Determining measurable target values to help evaluate the waterbody's condition in relation to the applicable water quality standards
- Quantifying the magnitude of pollutant contribution from their sources
- Determining the TMDL for each pollutant based on the allowable loading limits for each waterbody-pollutant combination
- Allocating the total allowable load (TMDL) into individual loads for each source

In Montana, restoration strategies and monitoring recommendations are also incorporated in TMDL documents to help facilitate TMDL implementation (see **Sections 9** and **10** of this document).

Basically, developing a TMDL for an impaired waterbody is a problem-solving exercise: The problem is excess pollutant loading that impairs a designated use. The solution is developed by identifying the total acceptable pollutant load (the TMDL), identifying all the significant pollutant-contributing sources, and identifying where pollutant loading reductions should be applied to achieve the acceptable load.

1.2 Water Quality Impairments and TMDLs Addressed by this Document

Table 1-1 below lists all of the impairment causes from the "2014 Water Quality Integrated Report" (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2014) that are addressed in this document (also see **Figure A-1** in **Appendix A**). Each pollutant impairment falls within a TMDL pollutant category (e.g., nutrients, temperature, or metals), and this document is organized by those categories.

TMDLs are completed for each waterbody – pollutant combination, and this document contains 18 TMDLs (**Table 1-1**). There are several non-pollutant types of impairment that are also addressed in this document. As noted above, TMDLs are not required for non-pollutants, although in many situations the solution to one or more pollutant problems will be consistent with, or equivalent to, the solution for one or more non-pollutant problems. The overlap between the pollutant TMDLs and non-pollutant impairment causes is discussed in **Section 8**. **Section 10** also provides some basic water quality solutions to address those non-pollutant causes not specifically addressed by TMDLs in this document.

Sediment and temperature TMDLs were previously completed for the Bitterroot TPA in 2011 (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011a). **Table A-1** in **Appendix A** includes impairment causes with completed TMDLs, as well as non-pollutant impairment causes that were addressed by those TMDLs.

Table 1-1. Water Quality Impairment Causes for the Bitterroot Watershed Addressed within this Document

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category	Impairment Cause Status *
Ambrose Creek, headwaters to mouth (Threemile Creek)	MT76H004_120	Nitrogen (Total)	Nutrients	TN TMDL contained in this document
		Phosphorus (Total)	Nutrients	TP TMDL contained in this document
Bass Creek, Selway-Bitterroot Wilderness boundary to mouth (un-named channel of Bitterroot River)	MT76H004_010	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document
		Nitrogen (Total)	Nutrients	TN TMDL contained in this document
		Phosphorus (Total)	Nutrients	TP TMDL contained in this document
Bear Creek, Selway-Bitterroot Wilderness boundary to mouth (Fred Burr Creek)	MT76H004_031	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document
Bitterroot River, East and West forks to Skalkaho Creek	MT76H001_010	Alteration in streamside or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document
Bitterroot River, Skalkaho Creek to Eightmile Creek	MT76H001_020	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document
		Sedimentation/Siltation	Sediment	Not impaired based on updated assessment
Bitterroot River, Eightmile Creek to mouth (Clark Fork River)	MT76H001_030	Lead	Metals	Lead TMDL contained in this document
		Sedimentation/Siltation	Sediment	Not impaired based on updated assessment
Blodgett Creek, Selway-Bitterroot Wilderness boundary to mouth (Bitterroot River)	MT76H004_050	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document
Kootenai Creek, Selway-Bitterroot Wilderness boundary to mouth (Bitterroot River)	MT76H004_020	Alteration in streamside or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document
		Low flow alterations	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document
Lick Creek, headwaters to mouth (Bitterroot River)	MT76H004_170	Aluminum	Metals	Aluminum TMDL contained in this document
		Chlorophyll-*a*	Not Applicable; Non-Pollutant	Addressed by a TP TMDL in this document
		Phosphorus (Total)	Nutrients	TP TMDL contained in this document
Lolo Creek, Mormon Creek to mouth (Bitterroot River)	MT76H005_011	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document
Lost Horse Creek, headwaters to mouth (Bitterroot River)	MT76H004_070	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document

Table 1-1. Water Quality Impairment Causes for the Bitterroot Watershed Addressed within this Document

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category	Impairment Cause Status *
Mill Creek, Selway-Bitterroot Wilderness boundary to the mouth (Fred Burr Creek)	MT76H004_040	Alteration in streamside or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a temperature TMDL in this document
		Low flow alterations	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document
		Temperature, water	Temperature	Temperature TMDL contained in this document
Miller Creek, headwaters to mouth (Bitterroot River)	MT76H004_130	Chlorophyll-*a*	Not Applicable; Non-Pollutant	Not impaired based on updated assessment
		Nitrate/Nitrite (Nitrite + Nitrate as N)	Nutrients	Not impaired based on updated assessment
		Nitrogen (Total)	Nutrients	Not impaired based on updated assessment
		Phosphorus (Total)	Nutrients	Not impaired based on updated assessment
Muddy Spring Creek, headwaters to mouth (Gold Creek)	MT76H004_180	Nitrate/Nitrite (Nitrite + Nitrate as N)	Nutrients	$NO_3 + NO_2$ TMDL contained in this document
North Burnt Fork Creek, confluence with South Burnt Fork Creek to Mouth (Bitterroot River)	MT76H004_200	Nitrogen (Total)	Nutrients	TN TMDL contained in this document
		Phosphorus (Total)	Nutrients	TP TMDL contained in this document
North Channel Bear Creek, headwaters to mouth (Fred Burr Creek)	MT76H004_032	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document
North Fork Rye Creek, headwaters to mouth (Rye Creek-Bitterroot River, South of Darby)	MT76H004_160	Alteration in streamside or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by TN and TP TMDLs in this document
		Nitrogen (Total)	Nutrients	TN TMDL contained in this document
		Phosphorus (Total)	Nutrients	TP TMDL contained in this document
Rye Creek, North Fork to mouth (Bitterroot River)	MT76H004_190	Nitrogen (Total)	Nutrients	TN TMDL contained in this document
		Phosphorus (Total)	Nutrients	TP TMDL contained in this document
Skalkaho Creek, headwaters to mouth (Bitterroot River)	MT76H004_100	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document
South Fork Lolo Creek, Selway-Bitterroot Wilderness boundary to mouth (Lolo Creek)	MT76H005_020	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document
		Physical substrate habitat alterations	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document

Table 1-1. Water Quality Impairment Causes for the Bitterroot Watershed Addressed within this Document

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category	Impairment Cause Status *
Sweathouse Creek, headwaters to mouth (Bitterroot River)	MT76H004_210	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document
		Phosphorus (Total)	Nutrients	TP TMDL contained in this document
Threemile Creek, headwaters to mouth (Bitterroot River)	MT76H004_140	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document
		Nitrate/Nitrite (Nitrite + Nitrate as N)	Nutrients	Addressed by a TN TMDL in this document
		Nitrogen (Total)	Nutrients	TN TMDL contained in this document
		Phosphorus (Total)	Nutrients	TP TMDL contained in this document
Tin Cup Creek, Selway-Bitterroot Wilderness boundary to mouth (Bitteroot River)	MT76H004_080	Alteration in streamside or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed in **Section 8** of this document

* TN = Total Nitrogen, TP = Total Phosphorus, NO_3 + NO_2 = Nitrite + Nitrate

1.3 What This Document Contains

This document addresses all of the required components of a TMDL and includes an implementation and monitoring strategy, as well as a strategy to address impairment causes other than nutrients, metals, and temperature. The TMDL components are summarized within the main body of the document. Additional technical details are contained in the appendices and attachments. In addition to this introductory section, this document includes:

Section 2.0 Bitterroot Watershed Project Area Description:
Describes the physical characteristics and social profile of the watershed.

Section 3.0 Montana Water Quality Standards
Discusses the water quality standards that apply to the Bitterroot watershed.

Section 4.0 Defining TMDLs and Their Components
Defines the components of TMDLs and how each is developed.

Sections 5.0 – 7.0 Nutrients, Metals, and Temperature TMDL Components (sequentially):
Each section includes (a) a discussion of the affected waterbodies and the pollutant's effect on designated beneficial uses, (b) the information sources and assessment methods used to evaluate stream health and pollutant source contributions, (c) water quality targets and existing water quality conditions, (d) the quantified pollutant loading from the identified sources, (e) the determined TMDL for each waterbody, (f) the allocations of the allowable pollutant load to the identified sources.

Section 8.0 Non-Pollutant Impairments:
Describes other problems that could potentially be contributing to water quality impairment and how the TMDLs in the plan might address some of these concerns. This section also provides recommendations for combating these problems.

Section 9.0 Water Quality Improvement Plan:
Discusses water quality restoration objectives and a strategy to meet the identified objectives and TMDLs.

Section 10.0 Monitoring Strategy and Adaptive Management:
Describes a water quality monitoring plan for evaluating the long-term effectiveness of the "Bitterroot Watershed Total Maximum Daily Loads and Framework Water Quality Protection Plan".

Section 11.0 Public Participation & Public Comments:
Describes other agencies and stakeholder groups who were involved with the development of this plan and the public participation process used to review the draft document. Addresses comments received during the public review period.

2.0 Bitterroot Watershed Project Area Description

This section includes a summary of the physical, ecological and cultural profile of the Bitterroot Watershed Project Area and is intended to provide background information to support total maximum daily load (TMDL) development. The maps referenced in this discussion are contained in **Appendix A**.

2.1 Physical Characteristics

The following information describes the physical profile of the Bitterroot TMDL Project Area and includes a discussion of location, topography, geology, soils, surface water, groundwater and climate.

2.1.1 Location

The project area encompasses approximately 2,857 square miles in southwestern Montana as shown in **Figure A-1**. Most of the project area resides in Ravalli County. Missoula County starts just north of Florence, MT. The most populated urban area is the city of Missoula. The city center is outside the Bitterroot Watershed Project Area but a portion of Missoula extends into the northern part of Bitterroot Watershed. The largest town completely contained within the Bitterroot Watershed is Hamilton, and other notable population centers include Lolo, Florence, Stevensville, Victor, Darby, and Sula. The project area is bounded by the Bitterroot Mountains to west and by the Sapphire Mountains to the east. All surface water drains to the northward flowing Bitterroot River and leaves the project area near Missoula. The Montana Department of Environmental Quality (DEQ) divides the state into TMDL Planning Areas (TPAs) for workload purposes based on topographic drainage boundaries and other considerations. In some instances, when TMDLs are developed, these planning areas are realigned into project areas. In this case, the Upper Lolo TPA, Bitterroot TPA, and Bitterroot Headwaters TPA were combined to create the Bitterroot Watershed Project Area (see **Figure A-2**).

2.1.2 Topography

Elevations in the Bitterroot Watershed Project Area range from approximately 3,100 feet above sea level at the confluence of Bitterroot and Clark Fork Rivers, to approximately 10,132 feet atop the summit of Trapper Peak in the Bitterroot Mountain Range. Valley bottom elevations average around 4,000 feet. Elevation is mapped on **Figure A-3.** The landscape is dominated by the Bitterroot Mountain Range to the west and the Sapphire Mountain Range to the east which are intercepted by the Bitterroot River Valley. The Bitterroot Mountains are typified by glacial landforms such as horns, tarns, cirques, and east-west oriented U-shaped valleys; alternatively, the Sapphire Mountains have more dendritic, or branching, V-shaped valleys. Other major topography patterns evident in **Figure A-3** are large valleys that drain the East and West Forks of the Bitterroot River and the Lolo Creek valley to the north.

Like topography, slopes in the project area vary greatly. The flat valley bottoms register 0° slopes but slopes as steep as 81° are also present in the Bitterroot Mountains. The average slope is 22°. **Figure A-4** depicts slopes in the project area calculated from the 30-meter National Elevation Dataset.

2.1.3 Geology

Figure A-5 and **Figure A-6** provide an overview of the generalized geology based on a 1:500,000 scale geologic map of Montana (Raines and Johnson, 1995). The first map displays standard geologic units and the second map indicates the dominant rock type found in each unit.

The oldest rocks in the Bitterroot Watershed Project Area date to the Precambrian Era. Commonly referred to as the collective Belt Series, it includes the Newland limestone, Ravalli Group, Missoula Group, Piegan Group, Pricard Formation, and Wallace Formation units. These sedimentary rocks cover 23% of the in the project area and are most common in the West Fork Bitterroot River drainage, the northern project area, and the Sapphire Mountains. During the Mesozoic Era, a massive igneous intrusion known as the Idaho batholith formed beneath the Belt Series rocks and uplifted the Bitterroot Mountains. This dominant geologic unit underlies 43% of the project area and is composed mostly of granitic gneiss. Small units of Tertiary volcanic rocks and dikes are scattered throughout the southern half of the project area, and sedimentary rocks from this time period are present in the northern Sapphire Mountains. Within roughly the last 2 million years, glaciers have had a major influence on portions of the project area. Valley and piedmont glaciers originating in the Bitterroot Mountains formed symmetrical U-shaped valleys aligned in an east-west fashion that are clearly visible in **Figure A-3**. These landscape features are not present in the eastern half of the project area because glaciers did not form in the Sapphire Mountains. The striking difference between the two mountain ranges surrounding the Bitterroot Valley is a classic example in the study of glacial geology. Glacial lakes formed as glaciers melted and retreated. When the Cordilleran Ice Sheet dammed the Clark Fork River near Idaho, a massive lake (Glacial Lake Missoula) was created that extended into the Bitterroot Valley. Sediments of this lake are exposed in the Lolo Creek area. The youngest rocks in the Bitterroot Watershed Project Area belong to the Alluvium geologic unit and are derived from the erosional and transportation forces of water. Alluvium can be found bordering the Bitterroot River and in the valley bottoms of most tributaries.

Like much of western Montana, abandoned hardrock and placer mines are scattered across the Bitterroot Watershed Project Area (also see **Figure A-5**). DEQ Abandoned Mine Lands Program and Montana Bureau of Mines and Geology (MBMG) estimate the presence of approximately 200 abandoned mines. Four of these mines (Ward Lode, Curlew, Montana Prince, and Bluebird) have been identified by the State of Montana as high priority mines for reclamation.

2.1.4 Soil

The United States General Soil Map developed by the National Cooperative Soil Survey and based on the STATSGO2 dataset was used to evaluate soil properties in the Bitterroot Watershed Project Area. **Figure A-7** depicts coverage of the four soil orders that exist within the project area. Soil orders are the broadest level of soil taxonomy and combine soils into units with similar physical and chemical attributes. Soils of the same order typically share properties because they formed under similar scenarios. Investigating the distribution of soil orders in the project area can help better understand soil behavior and potential effects to water quality.

Inceptisols are the most common soil order accounting for 52% of the project area. Inceptisols are the second least developed of the 12 soil orders and have only a slight degree of weathering either because they are considered geologically young or because the conditions under which they exist have only led to a slight modification from their original state. The cold climate of the Bitterroot Watershed Project Area is likely driver of immature soil profiles seen in the Inceptisol class. Mollisols are the second most widespread soil order (16%) and are defined by a humus-rich surface horizon. Regarded as some of the most agriculturally productive soils in the world, the largest grouping of these soils in the project area is found in the Bitterroot River valley where agricultural land uses are concentrated (see **Figure A-18**). They typically develop under grasslands and the suborder present in the Bitterroot Watershed Project Area is distinguished from other Mollisols because it forms in semiarid climates that have erratic precipitation (Brady and Weil, 2002). The third most common soil order is Entisols, which are represented on 8% of the landscape. Entisols have little to no profile development and are regarded as the least developed soil order. Most Entisols in the Bitterroot Watershed Project Area are alluvial, or river-derived in nature. Lastly, Alfisols are found scattered across 5% of the project area and are known for being more weathered the previously mentioned soil orders. These soils are moderately leached and characterized by a subsurface silicate clay horizon (Brady and Weil, 2002). The remainder of the project area either lacks soil order data or is simply bare rock.

A soil's susceptibility to erosion is a property especially relevant to TMDLs when reviewing upland pollutant sources. Erodibility is mapped in **Figure A-8** using the K-factor from the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978). The K-factor is an inherent property of soil that is independent of rainfall, slope, vegetation cover, and management differences. Values range from 0 to 1, with a greater value corresponding to greater potential for erosion. Soil erodibility is assigned to the following ranges: low (0.0-0.2), moderate-low (0.21-0.30) and moderate-high (0.31-0.40). Values greater than 0.4 are considered highly susceptible to erosion. The majority of project area soils are identified as having a low susceptibility to erosion (61%). Moderate-low susceptibility soils are represented on 6% of the project area and moderate-high susceptibility soils are mapped across 12% of the project area. Portions of the Threemile Creek, Ambrose Creek, and North Burnt Fork Creek watersheds contain soils with K-factors greater than 0.4, considered highly susceptible to erosion. Project area-wide, less than 2% of the soils are considered highly susceptible to erosion. The remainder of the project area either lacks K-factor data or is simply bare rock.

2.1.5 Surface Water

The Bitterroot Watershed Project Area matches the 4th Code Bitterroot Watershed (HUC 17010205) and contains 19 smaller 5th code watersheds as shown in **Figure A-9**. All lands drain to the Bitterroot River, which flows north, and water is transported out of the project area where the Bitterroot River joins the Clark Fork River just west of Missoula, MT. The project area is part of the much larger Columbia River basin which eventually discharges into the Pacific Ocean. No stream pertinent to this document has received protections granted by the National Wild and Scenic River Act. **Figure A-9** also categorizes TMDL streams pertinent to this document by pollutant group. Miller Creek was previously listed for Nitrate/Nitrite, Total Nitrogen, and Total Phosphorus, but recent data indicate water quality is not impaired by nutrients. The updated listing status will be incorporated into the 2016 Integrated Report.

The United States Geological Survey (USGS) has established numerous monitoring and gaging stations in the project area. As indicated in **Figure A-9** and detailed in **Table 2-1**. As of July 2014, four sites are actively recording continuous data. One site monitors West Fork Bitterroot River below the Painted Rocks Dam. Three other sites, spread across the project area, measure continuous streamflow on the Bitterroot River and also possess datasets with sporadic water quality samples.

Table 2-1. Active USGS Gage Stations in the Bitterroot Watershed Project Area

Station ID	Station Description	Latitude	Longitude	Data Range*
12342500	West Fork Bitterroot River nr Conner MT	45.724828	-114.282294	1901-present
12344000	Bitterroot River near Darby MT	45.97205	-114.141233	1937-present
12350250	Bitterroot River at Bell Crossing nr Victor MT	46.4432	-114.123767	1987-present
12352500	Bitterroot River near Missoula MT	46.831739	-114.054861	1898-present

*Data not continuous for entire period of record

The monthly hydrograph for the Bitterroot River gaging station nearest to the mouth is listed in **Figure 2-1**. One hundred and fourteen years of recorded data at this site indicate flows most often peak during June and reach a minimum in September. Discharge is relatively constant from October through February, after which time a large increase in flows is observed until baseflow returns six months later. This pattern is typical of snowmelt-dominated river systems in Montana. Droughts and high temperatures in recent years have forced Montana Fish Wildlife and Parks (FWP) to place temporary restrictions on summer fishing (Montana Fish, Wildlife and Parks, 2013). Although other TMDL streams do not have streamflow datasets as robust, they are expected to have a similarly timed hydrograph of a smaller magnitude.

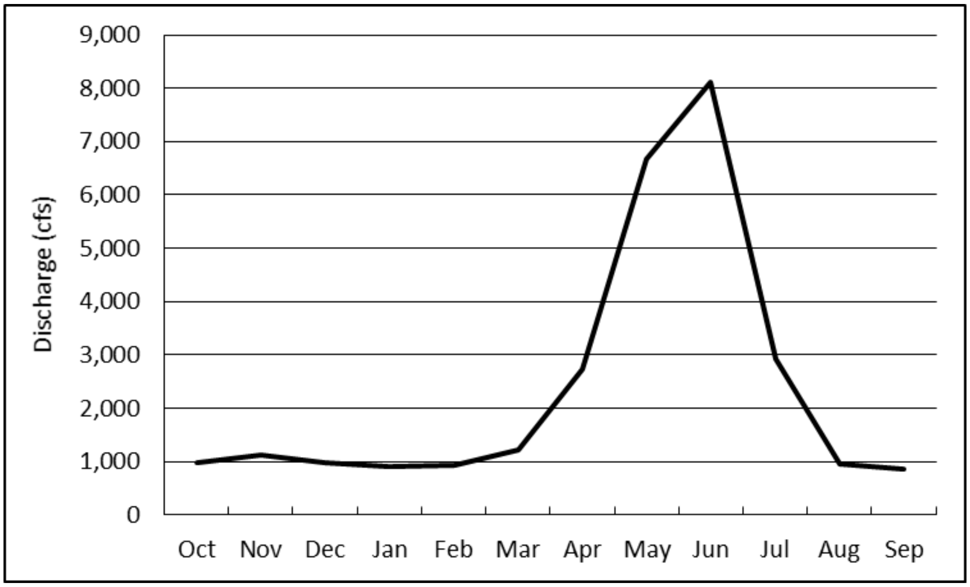


Figure 2-1. Mean Monthly Mean Discharge of Bitterroot River near Missoula MT #12352500 (1899-2013)

2.1.6 Groundwater

Figure A-10 depicts groundwater wells and distinguishes those with water quality data available online MBMG's Groundwater Information Center. As of July 2013 there were approximately 21,410 wells in the Bitterroot Watershed Project Area; 390 have associated water quality information (Montana Mines and Geology, 2013). As one would expect, well distribution largely follows population density (see **Figure A-15**) with the highest concentrations located in the Bitterroot Valley extending from Hamilton to Missoula.

2.1.7 Climate

Climate in the Bitterroot Watershed Project Area varies greatly. Precipitation ranges from 11 inches per year in the Bitterroot Valley between Victor and Hamilton, to 90 inches per year in the Bitterroot Mountains. Precipitation trends closely follow elevation: significant moisture falls in the mountains and the quantity gradually decreases with elevation. Average annual precipitation isolines for the time period 1981-2010 are mapped on **Figure A-11** using data provided by Oregon State University's PRISM Group (PRISM Climate Group, 2013).

Monthly climate averages provided by the Western Regional Climate Center are presented in **Table 2-2** for Hamilton, MT. As shown by this data, temperatures tend to peak in the mid-80s during July and

August. The coldest temperatures are observed in the December through February timeframe; however data from the National Climate Data Center show that every month of the year has experienced temperatures below freezing. The maximum temperature on record is 105°F and the minimum is -39°F. Precipitation is fairly constant, averaging less than 2 inches a month with the wettest months being May and June. The climate described for Hamilton is milder and drier than much of the project area. Significant amounts of snowfall occur during the winter, especially in the mountains, which drive river hydrographs as described in **Section 2.1.5**.

Table 2-2. Monthly Climate Summary for Hamilton, MT (1894-2004)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Max. Temperature (F)	35	41	49	59	68	75	85	83	72	60	45	36
Average Min. Temperature (F)	17	20	26	33	40	46	51	49	42	33	25	19
Average Total Precipitation (in.)	1.0	0.8	0.7	0.9	1.6	1.7	0.8	0.9	1.1	0.9	1.0	0.9
Average Total Snowfall (in.)	7.1	4.1	4.4	0.5	0.3	0	0	0	0	0.2	3.1	6.0
Average Snow Depth (in.)	2	2	1	0	0	0	0	0	0	0	1	1

2.2 Ecological Characteristics

The following information describes the ecological profile of the Bitterroot Watershed Project Area and includes a discussion of ecoregions, fires, aquatic life and terrestrial life.

2.2.1 Ecoregion

Ecoregions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources (Woods et al., 2002). The classification incorporates a wide array of subjects including geology, physiography, vegetation, climate, soils, land use, wildlife and hydrology. There are multiple levels, each successive tier more detailed than the previous. Levels III and IV are most commonly used for these types of environmental analyses. Besides providing a basic description of the environment, ecoregions are additionally important to TMDL investigations because numeric nutrient criteria depend on the ecoregion a stream segment is located in.

The spatial distribution of ecoregions within the Bitterroot Watershed Project Area is mapped on **Figure A-12**. The majority (58%) of the project area is associated with the level III Idaho Batholith ecoregion. This category is most commonly represented by the Eastern Batholith level IV ecoregion. The East and West Fork drainages of the Bitterroot River are classified under this level IV ecoregion, which is described as a mountainous, forested landscape, with subalpine fir, Douglas-fir, and ponderosa pine representing the climax vegetation. Common land uses include logging, grazing, mining, and recreation. It is also noted that the alkalinity of surface waters tends to be very low and is attributable to the intrusive Cretaceous Idaho Batholith rock that underlay the region (Montana Natural Heritage Program, 2001). As shown in **Table 2-3**, the Glaciated Bitterroot Mountain and Canyons level IV ecoregion is recognized across roughly 17% of the project area and can be found on the west side of the project area in the Bitterroot Mountains. Multiple TMDL streams originate in this ecoregion such as Bass Creek, Sweathouse Creek, Mill Creek, and Lick Creek. Similar to the Eastern Batholith geologically, this ecoregion receives more precipitation (up to 70 inches annually), has higher elevations, and has more evidence of glacial activity such as tills and outwash deposits. Climax vegetation is also similar to the Eastern Batholith with the addition of Engelmann spruce. The remaining lands listed under the Idaho Batholith level III ecoregion fall into either the High Idaho Batholith or the Lochsa Uplands. Lands categorized as High Idaho Batholith are described as high elevation, alpine landscapes with poorly developed, rocky soils, wind-blown subalpine fir and whitebark pine forests, and tundra-like meadows and wetlands above the treeline. The Lochsa Uplands is distinguished by the presence of hemlock and cedar forests.

The second most common (33%) level III ecoregion in the project area is identified as the Middle Rockies ecoregion. This category is most commonly represented by the extensive area running down the middle of the project area named the Bitterroot-Frenchtown Valley level IV ecoregion. Every TMDL stream but two (North Fork Rye Creek and Muddy Spring Creek), flow through portions of this ecoregion described as containing gentle hills, fans, floodplains, wetlands, and riparian forest. Protected by the Bitterroot to the west and Sapphire Mountains to the east, this region is sheltered from high winds and severe weather. In the valley, irrigated and non-irrigated agriculture is extensive as are residential and industrial development (Montana Natural Heritage Program, 2001). To the east of the valley lies the Rattlesnake-Blackfoot-South Swan-Northern Garnet-Sapphire Mountains level IV ecoregion. In this area, sedimentary belt series rocks are more predominant and less precipitation falls as a consequence of the Bitterroot Mountain's rain shadow.

The final level III ecoregion, the Northern Rockies, is represented in the Grave Creek Range-Nine Mile Divide category located in the northern portion of the project area in the Lolo Creek basin. This area is described as forested mountains underlain by argillite and quartz (Montana Natural Heritage Program, 2001). The remaining level IV ecoregions make up less than half a percent of the total project area.

Table 2-3. Ecoregion distribution in the Bitterroot Watershed Project Area

Level III Ecoregion	Level IV Ecoregion	Acres	Square Miles	% Total
Idaho Batholith	Eastern Batholith	608,418	951	33.5%
	Glaciated Bitterroot Mountains and Canyons	306,884	480	16.9%
	High Idaho Batholith	103,562	162	5.7%
	Lochsa Uplands	41,159	64	2.3%
Middle Rockies	Alpine Zone	798	1.2	0.04%
	Bitterroot-Frenchtown Valley	328,093	513	18.1%
	Flint Creek-Anaconda Mountains	332	0.5	0.02%
	Rattlesnake-Blackfoot-South Swan-Northern Garnet-Sapphire Mountains	271,117	424	14.9%
Northern Rockies	Grave Creek Range-Nine Mile Divide	155,584	243	8.6%
	St. Joe Schist-Gneiss Zone	108	0.2	0.01%

2.2.2 Fire

The timing and extent of wildfires are important to understand for TMDL investigations because burned landscapes behave differently from a water quality and pollutant loading perspective. **Figure A-13** depicts all known fire perimeters that burned in the project area from 1889 through 2013 (Gibson and Morgan, 2009; U.S. Geological Survey, 2013). The median annual acreage burned during this 124 year period of record is 1,490 acres or 2.3 square miles. The largest fire year on record is 2000 in which an estimated 487 square miles or 17% of the project area burned. The two most recent fires occurred in 2013. The Lolo Creek Complex, burned 10,886 acres or 17 square miles directly west of the town of Lolo and spanned across US Highway 12. The Gold Pan Complex burned 3,476 acres or 5 square miles of the Bitterroot Mountains in the West Fork Bitterroot River drainage.

2.2.3 Aquatic and Terrestrial Life

The State of Montana designates species of concern that are considered at risk because of declining population trends, threats to their habitats or restricted distribution. Within the Bitterroot Watershed Project Area three fish species are identified as such: bull trout (*Salvenlinus confluentus*), westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) and Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*). The distribution of these three species is mapped on **Figure A-14**. Bull trout populations are the most threatened. The US Fish and Wildlife Service (USFWS) has listed bull trout as threatened under the federal Endangered Species Act since 1998 due to habitat loss and degradation, introduction of non-native fish, fragmentation from dams and other barriers, and historical overharvesting. The Plum Creek Timber Company and the Montana Department of Natural Resources and Conservation (DNRC) have committed to specific conservation actions aimed at minimizing and mitigating impacts to bull trout from forest management activities on their lands (Plum Creek Timber Co., 2000; Montana Department of Natural Resources and Conservation, 2010). Like the bull trout, westslope cutthroat trout are sensitive to excess fine sediment and require cold water to survive. Habitat loss and degradation is a significant factor for population declines although westslope cutthroat trout are further threatened by their ability hybridize with introduced rainbow trout (Montana Natural Heritage Program and Montana Fish, Wildlife and Parks, 2013). Yellowstone cutthroat trout have similar habitat requirements as westslope cutthroat, but have a smaller range centered around Yellowstone National Park. Yellowstone cutthroat populations have suffered from hybridization and loss of tributary spawning habitat (Montana Natural Heritage Program and Montana Fish, Wildlife and Parks, 2014).

The Bitterroot Watershed Project Area also encompasses the range of several terrestrial species of concern. The USFWS has listed two mammals as threatened under the Endangered Species Act: grizzly bear (*Ursus arctos*) and Canada Lynx (*Lynx canadensis*). Two additional species are identified as candidates for protection under the act: wolverine (*Gulo gulo*) and whitebark pine (*Pinus albicaulis*).

2.3 Cultural Characteristics

The following information describes the cultural profile of the Bitterroot Watershed Project Area and includes a discussion of population, transportation networks, land ownership, land cover/use, and point sources.

2.3.1 Population

The population of Bitterroot Watershed Project Area, estimated using 2010 census block densities, is 74,485 people. This population is concentrated in the Bitterroot River valley and clustered around multiple towns that are connected by the US Highway 93 corridor as shown in **Figure A-15**. The remaining area is rural and sparsely populated or uninhabited wilderness. A portion of Missoula, with a population 66,788 in 2010, extends into the northern project area; however, the largest town completely contained within the Bitterroot Watershed is Hamilton, with a population of 4,348. Lolo is slightly smaller than Hamilton with a population of 3,892 and Stevensville is listed as 1,809. The remaining towns have less than 1,000 residents. The number of people living in the Bitterroot Watershed has greatly risen in recent decades. From 2000 to 2010, Missoula County experienced an 18% population growth and Ravalli County experienced an 11.5% growth. The demographics of Ravalli County resemble the rest of the state. A high percentage of the population, over 95% identify as white and 92% possess a high school diploma. Twenty-two percent of the population is younger than 18 and the median household income is $40,525 (United States Census Bureau, 2014).

Septic systems have the ability to affect the quality of nearby surface water if not properly functioning or maintained. When nitrogen in household wastewater is exposed to oxygen in soil, nitrate, a more mobile form of nitrogen, is produced. Nitrate can subsequently migrate to surface waters thereby damaging aquatic life resources. Nitrate additionally poses a human health risks if drinking water wells are contaminated. As **Figure A-16** shows, septic system distribution in the project area closely matches the population density map. Residents and businesses within the serviced areas of Lolo, Stevensville, Hamilton, Missoula, and Darby send effluent to wastewater treatment facilities. These cities have Montana Pollutant Discharge Elimination (MPDES) permits through DEQ to discharge treated effluent into the Bitterroot River.

2.3.2 Transportation Networks

The most significant transportation route in the Bitterroot Watershed Project Area is US Highway 93 which bisects the watershed in half. Highway 93 connects Missoula in the north to Sula in the southeast. Continuing south on Highway 93 out of the project area will lead to the town of Salmon, Idaho.
US Highway 12 splits from Highway 93 in Lolo, following Lolo Creek west over the state line. Another significant Highway 93 junction located south of Hamilton with Montana Route 38, also known as Skalkaho Highway, allows travel between the Bitterroot Valley and Phillipsburg, MT. Unpaved roads built primarily for accessing timber stands and private property are also common. Montana Rail Link owns a rail line extending from Missoula to Darby. Lastly, there are two small, public airports in the project area. One in Stevensville and another in Hamilton.

2.3.3 Land Ownership

National Forests managed by the US Forest Service (USFS) dominate land ownership in the Bitterroot Watershed Project Area as shown in **Figure A-17** and detailed in **Table 2-4**. The project area encompasses most of the Bitterroot National Forest and spans the territory of four ranger districts: Stevensville, Darby, West Fork, and Sula. A northern portion of the project area is managed by the Lolo National Forest out of the Missoula Ranger District office. The USFS manages lands for sustainable forest harvest and resource extraction, a diverse array of recreational activities, the recovery of threatened and endangered species, and for overall ecological integrity. Both forests list maintaining and enhancing water quality and fishery resources as a goal in their overarching forest plans (United States Forest Service, 1986; U.S. Department of Agriculture, Forest Service, Bitterroot National Forest, 1987). USFS lands also include two federally designated wilderness areas: the Anaconda-Pintlar Wilderness in the southeast and the Selway-Bitterroot Wilderness to the west. Combined, these wilderness areas account for 16% of the total project area.

Private lands are the second most common ownership category (24%) and are clustered in the Bitterroot River valley bottom. Private timber lands account for another 2% of the project area. These lands are actively managed to produce wood products by private companies. Some companies have directives to protect natural resources such as Native Fish Habitat Conservation Plans for bull trout (Plum Creek Timber Co., 2000).

The State of Montana owns land in the project area and manages it for a variety of uses. The 62 square miles of State Trust lands are managed help fund public schools, while the Montana Department of Resources and Conservation (DNRC) owns land under Painted Rocks Reservoir, and the state wildlife and recreation agency, Montana Fish, Wildlife and Parks (FWP) administers activities on another 15 square miles. FWP lands are split between numerous small acreage fishing access sites and two larger wildlife management areas (Threemile and Calf Creek) that help preserve elk winter range. The United States Fish and Wildlife Service (USFWS) operates the 2,865 acre Lee Metcalf National Wildlife Refuge as a sanctuary for natural resources, wildlife conservation and recreation. The nonprofit, environmental organization the Nature Conservancy also owns 16 square miles, some in the Miller Creek drainage. Other ownership categories such as the department of transportation and city governments, account for a small percentage of the project area.

Table 2-4. Land ownership in the Bitterroot Watershed Project Area

Owner	Square Miles	Acres	% Total
US Forest Service	2,024	1,295,482	71%
Other/Private	684	437,587	24%
Montana State Trust Lands	62	39,662	2.1%
Private Timber	50	31,974	1.8%
The Nature Conservancy	16	10,396	0.6%
Montana Fish, Wildlife and Parks	15	9,381	0.5%
US Fish and Wildlife Service	4.5	2,865	0.2%
Montana Department of Natural Resources and Conservation	1.5	954	0.05%
City Government	0.2	140	0.01%
Montana Department of Transportation	0.1	34	0.002%

2.3.4 Land Cover and Use

Land cover within the project area is dominated by conifer forests. The drier conifer forest category (xeric-mesic) makes up 29% of the total project area while a separate conifer category that receives more precipitation (mesic-wet) covers another 13%. Land cover extent is depicted in **Figure A-18** and detailed in **Table 2-5**. Land cover classes are identified using the Montana Natural Heritage Program's Level 2 Land Cover spatial coverage (Montana Natural Heritage Program and Montana Fish, Wildlife and Parks, 2013). Due in large part to the 2000 wildfires (see **Section 2.2.2**), the second most common land cover is classified as recently burned. Montane grassland, where grasses and forbs are more common than woody vegetation, is the next most common land cover at 15%. The remaining land cover categories are represented on less than 5% of the landscape. Some of these classes, while rare in terms of overall project area distribution, are common within TMDL watersheds and likely have a larger influence than their respective project area percentages would indicate. For example, agricultural activities cover less than 4% of the overall project area but account for 22% of the North Burnt Fork Creek watershed. Agricultural activities are also present in every other TMDL watershed except Muddy Springs Creek. Irrigating and managing these lands can have a significant influence on streamflows and water quality. Many other TMDL watersheds also have a higher percentage of developed land cover, which includes road surfaces, than the 4% calculated for the project area statistic. Lands recovering from forest harvest are most common in the Lolo Creek and Miller Creek watershed and are estimated at 3% of the total project area.

Table 2-5. Land Cover Distribution in the Bitterroot Watershed Project Area

Land Cover	Square Miles	Acres	% Total
Conifer-dominated forest and woodland (xeric-mesic)	825.1	528,054	28.88%
Recently burned	615.0	393,582	21.53%
Montane Grassland	432.3	276,701	15.13%
Conifer-dominated forest and woodland (mesic-wet)	382.5	244,799	13.39%

Table 2-5. Land Cover Distribution in the Bitterroot Watershed Project Area

Land Cover	Square Miles	Acres	% Total
Developed	119.4	76,427	4.18%
Agriculture	105.3	67,378	3.69%
Floodplain and Riparian	102.8	65,816	3.60%
Harvested Forest	92.6	59,287	3.24%
Deciduous Shrubland	78.8	50,437	2.76%
Cliff, Canyon and Talus	25.1	16,090	0.88%
Wet meadow	23.6	15,072	0.82%
Deciduous dominated forest and woodland	20.1	12,873	0.70%
Alpine Sparse and Barren	16.6	10,631	0.58%
Open Water	12.7	8,134	0.44%
Sagebrush Steppe	1.6	1,007	0.06%
Bog or Fen	1.0	669	0.04%
Herbaceous Marsh	0.6	376	0.02%
Mixed deciduous/coniferous forest and woodland	0.5	317	0.02%
Forested Marsh	0.4	259	0.01%
Introduced Vegetation	0.3	208	0.01%
Mining and Resource Extraction	0.2	132	0.01%
Sagebrush-dominated Shrubland	0.0	14	0.00%
Alpine Grassland and Shrubland	0.0	9	0.00%
Bluff, Badland and Dune	0.0	8	0.00%

2.3.5 Point Sources

There are 38 active point sources permitted under the Montana Pollutant Discharge Elimination System (MPDES) in the Bitterroot Watershed Project Area according to Environmental Protection Agency's (EPA) Integrated Compliance Information System database as of July 2014. The majority of these (26) are general permits for stormwater derived from construction activities, dewatering construction areas, or sand and gravel pits. Five municipalities are allowed to discharge treated sewage into surface waters (Hamilton, Lolo, Stevensville, Darby and Missoula). Four additional permits cover the application of aquatic herbicide or pesticide. The remaining general permits involve a motor vehicle facility, an airport, and a metal fabrication shop. The lower segment of the Bitterroot River (MT76H001_030) is the only TMDL stream listed as a receiving water for a point source.

3.0 MONTANA WATER QUALITY STANDARDS

The federal Clean Water Act provides for the restoration and maintenance of the chemical, physical, and biological integrity of the nation's surface waters so that they support all designated uses. Water quality standards are used to determine impairment, establish water quality targets, and to formulate the total maximum daily loads (TMDLs) and allocations.

Montana's water quality standards and water quality standards in general include three main parts:

1. Stream classifications and designated uses
2. Numeric and narrative water quality criteria designed to protect designated uses
3. Nondegradation provisions for existing high-quality waters

Montana's water quality standards also incorporate prohibitions against water quality degradation as well as point source permitting and other water quality protection requirements.

Nondegradation provisions are not applicable to the TMDLs developed within this document because of the impaired nature of the streams addressed. Those water quality standards that apply to this document are reviewed briefly below. More detailed descriptions of Montana's water quality standards may be found in the Montana Water Quality Act (75-5-301,302 Montana Code Annotated (MCA)), and Montana's Surface Water Quality Standards and Procedures (ARM 17.30.601-670) and Circular DEQ-7 (Montana Department of Environmental Quality, 2012).

3.1 STREAM CLASSIFICATIONS AND DESIGNATED BENEFICIAL USES

Waterbodies are classified based on their designated uses. All Montana waters are classified for multiple uses. Waters classified as B-1 are to be maintained suitable for drinking, culinary, and food processing purposes after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply. While some of the waterbodies might not actually be used for a designated use (e.g., drinking water supply), their water quality still must be maintained suitable for that designated use. More detailed descriptions of Montana's surface water classifications and designated uses are provided in **Appendix B**. Department of Environmental Quality's (DEQ) water quality assessment methods are designed to evaluate the most sensitive uses for each pollutant group addressed within this document, thus ensuring protection of all designated uses (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011b). For streams in Western Montana, the most sensitive uses assessed for nutrients are aquatic life and primary contact recreation; for metals are drinking water and/or aquatic life; and for temperature is aquatic life. DEQ determined that 11 waterbody segments in the Bitterroot Watershed Project Area do not meet the nutrient, temperature, and metals water quality standards (**Table 3-1**).

Table 3-1. Impaired Waterbodies and their Impaired Designated Uses in the Bitterroot Watershed Project Area

Waterbody & Location Description	Waterbody ID	Impairment Cause *	Impaired Use(s)
Ambrose Creek, headwaters to mouth (Threemile Creek)	MT76H004_120	Nitrogen (Total)	Aquatic Life Primary Contact Recreation
		Phosphorus (Total)	Aquatic Life Primary Contact Recreation
Bass Creek, Selway-Bitterroot Wilderness boundary to mouth (un-named channel of Bitterroot River)	MT76H004_010	Nitrogen (Total)	Aquatic Life Primary Contact Recreation
		Phosphorus (Total)	Aquatic Life Primary Contact Recreation
Bitterroot River, Eightmile Creek to mouth (Clark Fork River)	MT76H001_030	Lead	Aquatic Life
Lick Creek, headwaters to mouth (Bitterroot River)	MT76H004_170	Aluminum	Aquatic Life
		Phosphorus (Total)	Aquatic Life Primary Contact Recreation
Mill Creek, Selway-Bitterroot Wilderness boundary to the mouth (Fred Burr Creek)	MT76H004_040	Temperature, water	Aquatic Life
Muddy Spring Creek, headwaters to mouth (Gold Creek)	MT76H004_180	Nitrate/Nitrite (Nitrite + Nitrate as N)	Aquatic Life Primary Contact Recreation
North Burnt Fork Creek, confluence with South Burnt Fork Creek to Mouth (Bitterroot River)	MT76H004_200	Nitrogen (Total)	Aquatic Life Primary Contact Recreation
		Phosphorus (Total)	Aquatic Life Primary Contact Recreation
North Fork Rye Creek, headwaters to mouth (Rye Creek-Bitterroot River, South of Darby)	MT76H004_160	Nitrogen (Total)	Aquatic Life Primary Contact Recreation
		Phosphorus (Total)	Aquatic Life Primary Contact Recreation
Rye Creek, North Fork to mouth (Bitterroot River)	MT76H004_190	Nitrogen (Total)	Aquatic Life Primary Contact Recreation
		Phosphorus (Total)	Aquatic Life Primary Contact Recreation
Sweathouse Creek, headwaters to mouth (Bitterroot River)	MT76H004_210	Phosphorus (Total)	Aquatic Life Primary Contact Recreation
Threemile Creek, headwaters to mouth (Bitterroot River)	MT76H004_140	Nitrate/Nitrite (Nitrite + Nitrate as N)	Aquatic Life Primary Contact Recreation
		Nitrogen (Total)	Aquatic Life Primary Contact Recreation
		Phosphorus (Total)	Aquatic Life Primary Contact Recreation

3.2 Numeric and Narrative Water Quality Standards

In addition to the use classifications described above, Montana's water quality standards include numeric and narrative criteria that protect the designated uses. Numeric criteria define the allowable concentrations, frequency, and duration of specific pollutants so as not to impair designated uses.

Numeric standards apply to pollutants that are known to have adverse effects on human health or aquatic life (e.g., metals, organic chemicals, and other toxic constituents). Human health standards are set at levels that protect against long-term (lifelong) exposure via drinking water and other pathways such as fish consumption, as well as short-term exposure through direct contact such as swimming. Numeric standards for aquatic life include chronic and acute values. Chronic aquatic life standards prevent long-term, low level exposure to pollutants. Acute aquatic life standards protect from short-term exposure to pollutants. Numeric standards also apply to other designated uses such as protecting irrigation and stock water quality for agriculture.

Narrative standards are developed when there is insufficient information to develop numeric standards and/or the natural variability makes it impractical to develop numeric standards. Narrative standards describe the allowable or desired condition. This condition is often defined as an allowable increase above "naturally occurring." DEQ often uses the naturally occurring condition, called a "reference condition," to help determine whether or not narrative standards are being met (see **Appendix B**).

For the Bitterroot Watershed Project Area, a combination of numeric and narrative standards are applicable. The numeric standards apply to metals and nutrients, and narrative standards are applicable for temperature. The specific numeric and narrative standards are summarized in **Appendix B**.

4.0 Defining TMDLs and Their Components

A total maximum daily load (TMDL) is a tool for implementing water quality standards and is based on the relationship between pollutant sources and water quality conditions. More specifically, a TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive from all sources and still meet water quality standards.

Pollutant sources are generally defined as two categories: point sources and nonpoint sources. Point sources are discernible, confined and discrete conveyances, such as pipes, ditches, wells, containers, or concentrated animal feeding operations, from which pollutants are being, or may be, discharged. Some sources such as return flows from irrigated agriculture are not included in this definition. All other pollutant loading sources are considered nonpoint sources. Nonpoint sources are diffuse and are typically associated with runoff, streambank erosion, most agricultural activities, atmospheric deposition, and groundwater seepage. Natural background loading is a type of nonpoint source.

As part of TMDL development, the allowable load is divided among all significant contributing point and nonpoint sources. For point sources, the allocated loads are called “wasteload allocations” (WLAs). For nonpoint sources, the allocated loads are called “load allocations” (LAs).

A TMDL is expressed by the equation: $TMDL = \Sigma WLA + \Sigma LA$, where:

ΣWLA is the sum of the wasteload allocation(s) (point sources)
ΣLA is the sum of the load allocation(s) (nonpoint sources)

TMDL development must include a margin of safety (MOS), which can be explicitly incorporated into the above equation. Alternatively, the MOS can be implicit in the TMDL. A TMDL must also ensure that the waterbody will be able to meet and maintain water quality standards for all applicable seasonal variations (e.g., pollutant loading or use protection).

Development of each TMDL has four major components:

- Determining water quality targets
- Quantifying pollutant sources
- Establishing the total allowable pollutant load
- Allocating the total allowable pollutant load to their sources

Although the way a TMDL is expressed can vary by pollutant, these four components are common to all TMDLs, regardless of pollutant. Each component is described in further detail in the following subsections.

Figure 4-1 illustrates how numerous sources contribute to the existing load and how the TMDL is defined. The existing load can be compared to the allowable load to determine the amount of pollutant reduction needed.

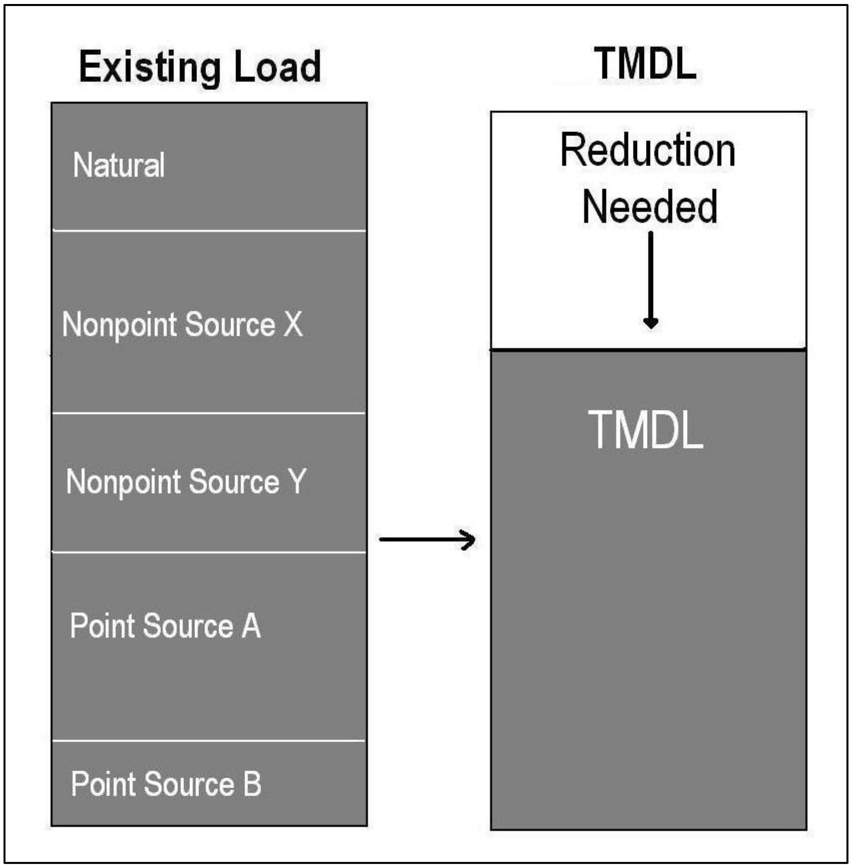


Figure 4-1. Schematic Example of TMDL Development

4.1 Developing Water Quality Targets

TMDL water quality targets are a translation of the applicable numeric or narrative water quality standard(s) for each pollutant. For pollutants with established numeric water quality standards, the numeric value(s) are used as the TMDL targets. For pollutants with narrative water quality standard(s), the targets provide a waterbody-specific interpretation of the narrative standard(s).

Water quality targets are typically developed for multiple parameters that link directly to the impaired beneficial use(s) and applicable water quality standard(s). Therefore, the targets provide a benchmark by which to evaluate attainment of water quality standards. Furthermore, comparing existing stream conditions to target values allows for a better understanding of the extent and severity of the problem.

4.2 Quantifying Pollutant Sources

All significant pollutant sources, including natural background loading, are quantified so that the relative pollutant contributions can be determined. Because the effects of pollutants on water quality can vary throughout the year, assessing pollutant sources must include an evaluation of the seasonal variability of the pollutant loading. The source assessment helps to define the extent of the problem by linking the pollutant load to specific sources in the watershed.

A pollutant load is usually quantified for each point source permitted under the Montana Pollutant Discharge Elimination System (MPDES) program. Nonpoint sources are quantified by source categories (e.g., unpaved roads) and/or by land uses (e.g., crop production or forestry). These source categories and land uses can be divided further by ownership, such as federal, state, or private. Alternatively, most, or all, pollutant sources in a sub-watershed or source area can be combined for quantification purposes.

Because all potentially significant sources of the water quality problems must be evaluated, source assessments are conducted on a watershed scale. The source quantification approach may produce reasonably accurate estimates or gross allotments, depending on the data available and the techniques used for predicting the loading (40 Code of Federal Regulation (CFR) Section 130.2(I)). Montana TMDL development often includes a combination of approaches, depending on the level of desired certainty for setting allocations and guiding implementation activities.

4.3 Establishing the Total Allowable Load

Identifying the TMDL requires a determination of the total allowable load over the appropriate time period necessary to comply with the applicable water quality standard(s). Although “TMDL” implies “daily load,” determining a daily loading may not be consistent with the applicable water quality standard(s), or may not be practical from a water quality management perspective. Therefore, the TMDL will ultimately be defined as the total allowable loading during a time period that is appropriate for applying the water quality standard(s) and which is consistent with established approaches to properly characterize, quantify, and manage pollutant sources in a given watershed. For example, sediment TMDLs may be expressed as an allowable annual load.

If a stream is impaired by a pollutant for which numeric water quality criteria exist, the TMDL, or allowable load, is typically calculated as a function of streamflow and the numeric criteria. This same approach can be applied when a numeric target is developed to interpret a narrative standard.

Some narrative standards, such as those for sediment, often have a suite of targets. In many of these situations it is difficult to link the desired target values to highly variable, and often episodic, instream loading conditions. In such cases the TMDL is often expressed as a percent reduction in total loading based on source quantification results and an evaluation of load reduction potential (**Figure 4-1**). The degree by which existing conditions exceed desired target values can also be used to justify a percent reduction value for a TMDL.

Even if the TMDL is preferably expressed using a time period other than daily, an allowable daily loading rate will also be calculated to meet specific requirements of the federal Clean Water Act. Where this occurs, TMDL implementation and the development of allocations will still be based on the preferred time period, as noted above.

4.4 Determining Pollutant Allocations

Once the allowable load (the TMDL) is determined, that total must be divided among the contributing sources. The allocations are often determined by quantifying feasible and achievable load reductions through application of a variety of best management practices and other reasonable conservation practices.

Under the current regulatory framework (40 CFR 130.2) for developing TMDLs, flexibility is allowed in allocations in that “TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure.” Allocations are typically expressed as a number, a percent reduction (from the current load), or as a surrogate measure (e.g., a percent increase in canopy density for temperature TMDLs).

Figure 4-2 illustrates how TMDLs are allocated to different sources using WLAs for point sources and LAs for natural and nonpoint sources. Although some flexibility in allocations is possible, the sum of all allocations must meet the water quality standards in all segments of the waterbody.

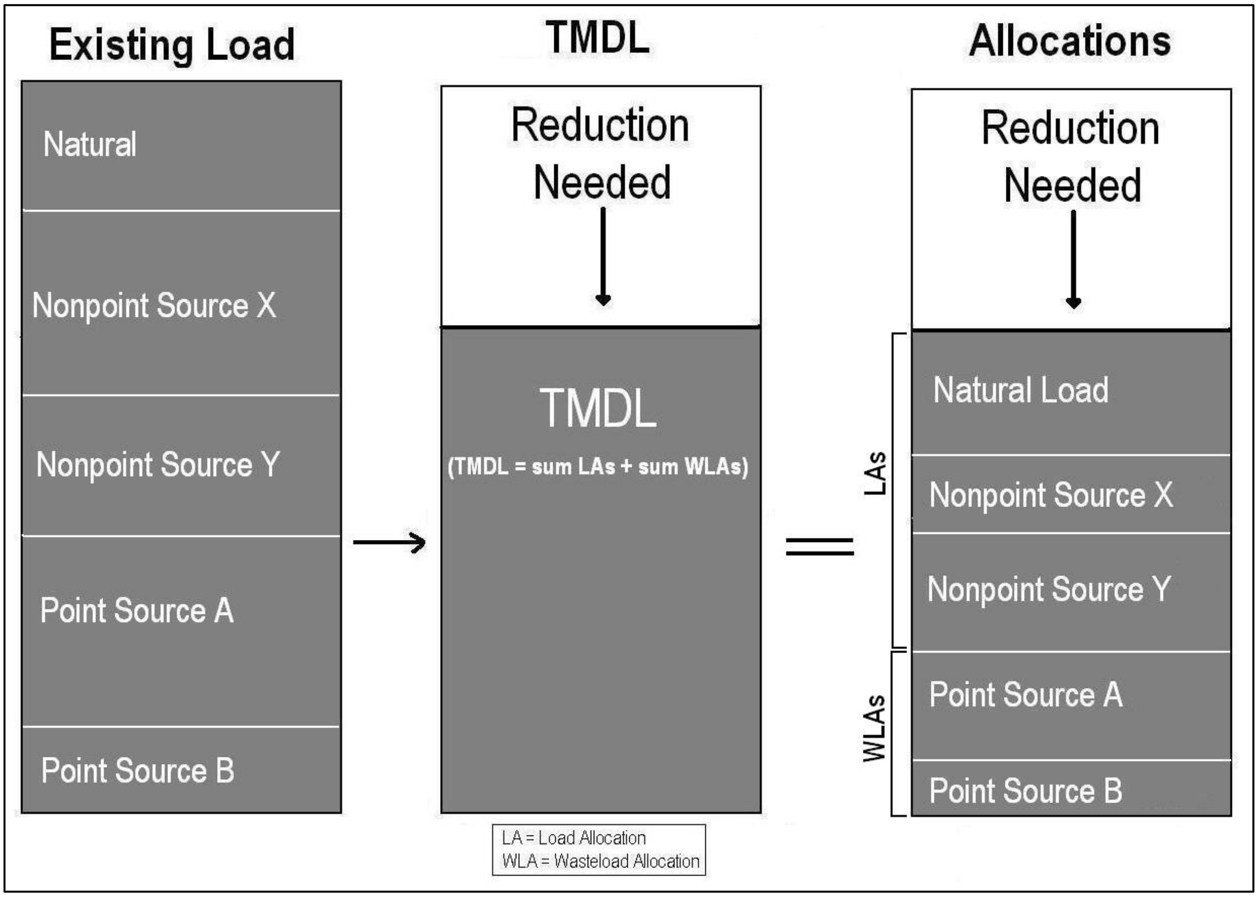


Figure 4-2. Schematic Diagram of a TMDL and its Allocations

TMDLs must also incorporate a margin of safety. The margin of safety accounts for the uncertainty, or any lack of knowledge, about the relationship between the pollutant loads and the quality of the receiving waterbody. The margin of safety may be applied implicitly by using conservative assumptions in the TMDL development process, or explicitly by setting aside a portion of the allowable loading (i.e., a TMDL = WLA + LA + MOS) (U.S. Environmental Protection Agency, 1999). The margin of safety is a required component to help ensure that water quality standards will be met when all allocations are achieved. In Montana, TMDLs typically incorporate implicit margins of safety.

When a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA is based on an assumption that nonpoint source load reductions will occur, the TMDL should provide reasonable assurances that nonpoint source control measures will achieve expected load reductions. For TMDLs in this document where there is a combination of nonpoint sources and one or more permitted point sources discharging into an impaired stream reach, the permitted point source WLAs are not dependent on implementation of the LAs. Instead, Department of Environmental Quality (DEQ) sets the

WLAs and LAs at levels necessary to achieve water quality standards throughout the watershed. Under these conditions, the LAs are developed independently of the permitted point source WLA such that they would satisfy the TMDL target concentration within the stream reach immediately above the point source. In order to ensure that the water quality standard or target concentration is achieved below the point source discharge, the WLA is based on the point source's discharge concentration set equal to the standard or target concentration for each pollutant unless the loading from individual point source is negligible based on no measureable impacts to water quality.

4.5 Implementing TMDL Allocations

The Clean Water Act (CWA) and Montana state law (Section 75-5-703 of the Montana Water Quality Act) require wasteload allocations to be incorporated into appropriate discharge permits, thereby providing a regulatory mechanism to achieve load reductions from point sources. Nonpoint source reductions linked to load allocations are not required by the CWA or Montana statute, and are primarily implemented through voluntary measures. This document contains several key components to assist stakeholders in implementing nonpoint source controls. **Section 9.0** discusses a restoration and implementation strategy by pollutant group and source category, and provides recommended best management practices (BMPs) per source category (e.g., grazing, cropland, urban, etc.). **Section 9.5** discusses potential funding sources that stakeholders can use to implement BMPs for nonpoint sources. Other site-specific pollutant sources are discussed throughout the document, and can be used to target implementation activities. DEQ's Watershed Protection Section helps to coordinate nonpoint implementation throughout the state and provides resources to stakeholders to assist in nonpoint source BMPs. Montana's Nonpoint Source Management Plan (available at http://www.deq.mt.gov/ wqinfo/nonpoint/nonpointsourceprogram.mcpx) further discusses nonpoint source implementation strategies at the state level.

DEQ uses an adaptive management approach to implementing TMDLs to ensure that water quality standards are met over time (outlined in **Section 10.0**). This includes a monitoring strategy and an implementation review that is required by Montana statute (see **Section 10.2**). TMDLs may be refined as new data become available, land uses change, or as new sources are identified.

5.0 Nutrient TMDL Components

This section of the document focuses on nutrients as a cause of water quality impairment in the Bitterroot project area. It describes: (1) how excess nutrients impair beneficial uses, (2) the affected stream segments, (3) the currently available data pertaining to nutrient impairments in the watershed, (4) the sources of nutrients based on recent studies, and (5) the proposed nutrient total maximum daily loads (TMDLs) and their rationales.

5.1 Nutrient Effects on Beneficial Uses

Nitrogen and phosphorus are naturally occurring elements required for healthy functioning of aquatic ecosystems. Streams in particular are dynamic systems that depend on a balance of nutrients, which can enter streams from various sources. Healthy streams strike a balance between organic and inorganic nutrients from sources such as natural erosion, groundwater discharge, and instream biological decomposition. This balance relies on autotrophic organisms (e.g., algae) to consume excess nutrients and on the cycling of biologically fixed nitrogen and phosphorus into higher levels on the food chain, as well as on nutrient decomposition (e.g., changing organic nutrients into inorganic forms). Human influences may alter nutrient cycling, damaging biological stream function and degrading water quality. The effects on streams of total nitrogen (TN), nitrate+nitrite (NO_3 + NO_2; a component of TN), and total phosphorus (TP) are all considered in assessing the effects on beneficial uses.

Excess nitrogen in the form of dissolved ammonia (which is typically associated with wastewater) can be toxic to fish and other aquatic life. Excess nitrogen in the form of nitrate in drinking water can inhibit normal hemoglobin function in infants. In addition, excess nitrogen and phosphorus from human sources can cause excess algal growth, which in turn depletes the supply of dissolved oxygen, killing fish and other aquatic life. Excess nutrient concentrations in surface water create blue-green algae blooms (Priscu, 1987), which can produce toxins lethal to aquatic life, wildlife, livestock, and humans. Aside from the toxicity effects, nuisance algae can shift the structure of macroinvertebrate communities, which may also negatively affect the fish that feed on macroinvertebrates (U.S. Environmental Protection Agency, 2010). Additionally, changes in water clarity, fish communities, and aesthetics can harm recreational uses, such as fishing, swimming, and boating (Suplee et al., 2009). Nuisance algae can also increase the cost of treating drinking water or pose health risks if ingested in drinking water (World Health Organization, 2003b).

5.2 Stream Segments of Concern

Department of Environmental Quality (DEQ) used data collected during the past several years to update nutrient assessments on streams in the Bitterroot project area. There were 15 waterbody segments in the Bitterroot project area that were previously listed for nutrient impairments, including 2 segments of the Bitterroot River, that were included in the assessment. Of those 15 waterbody segments, 9 remained impaired and the results of the assessment has been reflected on the 2014 303(d) List. The streams of concern are Ambrose, Bass, Lick, Muddy Spring, North Burnt Fork, North Fork Rye, Rye, Sweathouse, and Threemile Creeks (**Figure 5-1**). **Table 5-1** identifies the streams of concern addressed in this document. The assessment results for the streams that will have TMDLS developed are presented in **Section 5.4**, along with an updated impairment summary (**Table 5-21**) for the Bitterroot project area.

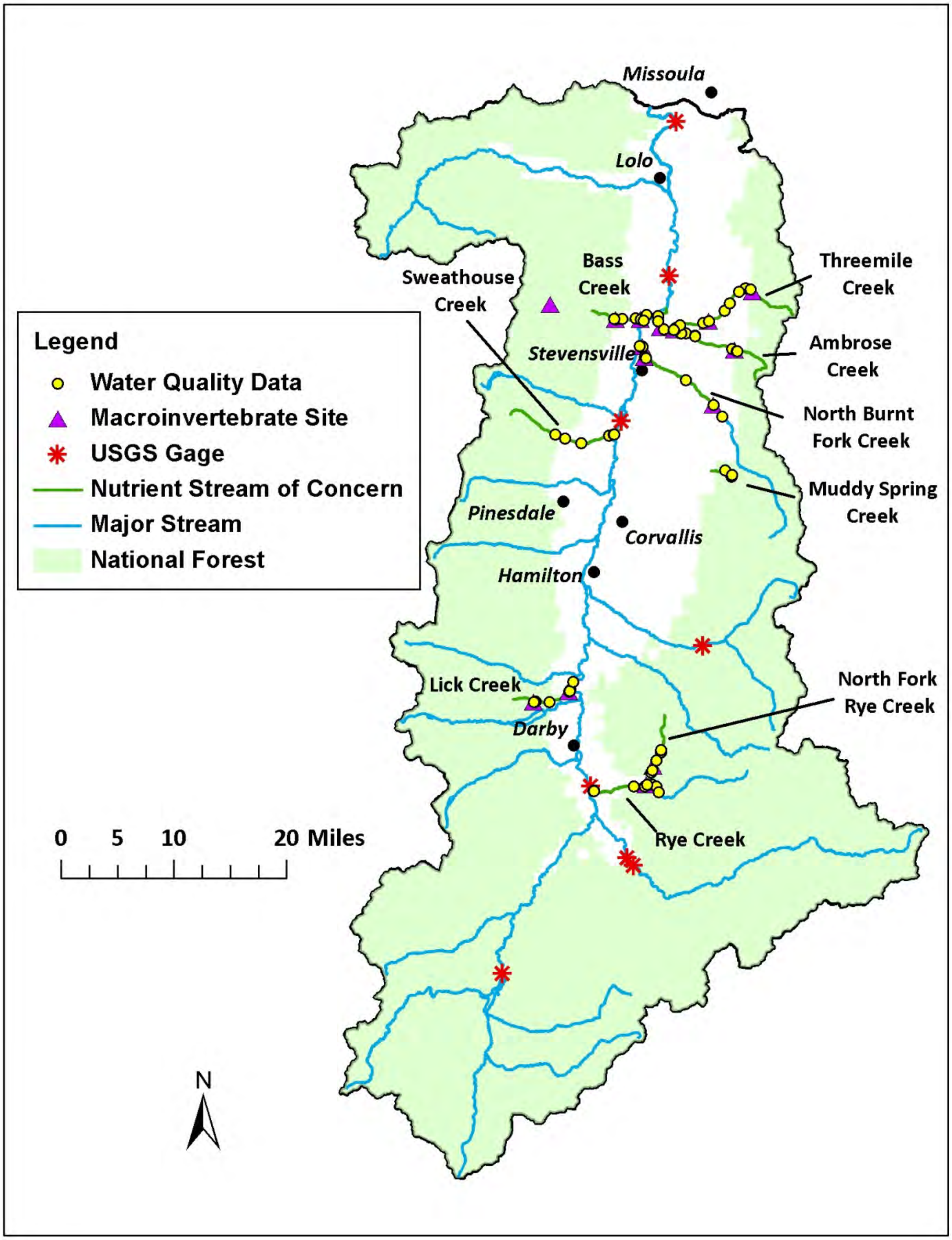


Figure 5-1. Nutrient Streams of Concern in the Bitterroot Project Area and Associated Sampling Locations

Table 5-1. Nutrient Stream Segments of Concern in the Bitterroot Project Area

Stream Segment	Waterbody ID
AMBROSE CREEK, headwaters to mouth (Threemile Creek)	MT76H004_120
BASS CREEK, Selway-Bitterroot Wilderness boundary to mouth	MT76H004_010
LICK CREEK, headwaters to mouth	MT76H004_170
MUDDY SPRING CREEK, headwaters to mouth (Gold Creek)	MT76H004_180
NORTH BURNT FORK CREEK, South Burnt Fork Creek to mouth	MT76H004_200
NORTH FORK RYE CREEK, headwaters to mouth (Rye Creek)	MT76H004_160
RYE CREEK, North Fork Rye Creek to mouth	MT76H004_190
SWEATHOUSE CREEK, headwaters to mouth	MT76H004_210
THREEMILE CREEK, headwaters to mouth	MT76H004_140

DEQ also collected data and updated assessments for the Bitterroot River (MT76H001_020 and MT76H001_030), Miller Creek (MT76H004_130), Sleeping Child Creek (MT76H004_090), Tin Cup Creek (MT76H004_080), and Willow Creek (MT76H004_110). The data clearly show that these streams consistently met the nutrient criteria used to assess impairment, and DEQ will be removing their nutrient impairment causes from Montana's list of impaired waterbodies and TMDLs will not be developed. The assessment results for these streams are contained in the DEQ assessment files and are documented in the 2014 Integrated Report, with the exception of Miller Creek, which will have the nutrient impairment causes removed in the 2016 Integrated Report.

5.3 Water Quality Assessment Method and Information Sources

DEQ's nutrient water quality assessment method has specific objectives and decision-making criteria for assessing the validity and reliability of data. DEQ uses a Data Quality Analysis (DQA) process to evaluate data for use in assessments and decision making. The DQA considers the representativeness, currency, and quality as well as the spatial and temporal components of the readily available data. The specific data requirements are detailed in the nutrient assessment method (Suplee and Sada de Suplee, 2011).

To assess nutrient conditions for TMDL development, DEQ compiled nutrient data and undertook additional monitoring. The following primary data sources represent the primary information used to characterize the water quality of the Bitterroot project area.

1) **DEQ Monitoring and Assessment and TMDL Sampling:** DEQ conducted water quality sampling from 2003 through 2012 to update impairment determinations and assist with the development of nutrient TMDLs.
2) **Tri-State Water Quality Data:** The Tri-State Water Quality Council, a non-profit organization, conducted water quality sampling as part of a two year project to assess the status of water quality and aquatic and riparian habitat in the Ambrose-Threemile watershed. Data were available from 2002-2007 from multiple sites on several streams in the Bitterroot project area.

Primary data sources include those collected in the assessment units (AUs) and within the specific waterbody segment(s). All water chemistry data used in the assessment and TMDL development were collected during the growing season for the Middle Rockies and Idaho Batholith Level III Ecoregion (July 1 - September 30). Benthic algae samples were collected for each stream and analyzed for chlorophyll-*a* and ash free dry mass (AFDM). Macroinvertebrate samples were also collected in each stream. DEQ used the most current data that was collected in the past 10 years. Only primary data sources that passed DEQ's DQA process were used to make impairment determinations. Nutrient data from the

Bitterroot project area are publicly available through Environmental Protection Agency's (EPA) STOrage and RETrieval database (STORET) and DEQ's EQuIS water quality databases.

Additional sources of information used to develop TMDL components include the following:

- Previous water quality studies by Ravalli County and Tri-State Water Quality Council
- United States Forest Service (USFS) grazing allotment and harvest information
- DEQ abandoned and active mine records
- Geospatial data and land use information including land cover, cropland and irrigation, septic systems, fire history, and silvicultural activities

The above information and water quality data are used to compare existing conditions to waterbody restoration goals (targets), to assess nutrient pollutant sources, and to help determine TMDL allocations. Data collected by DEQ were reviewed to ensure quality assurance quality control requirements were met. DEQ determined that the data used were of quality and scope extensive enough to make an impairment determination and for use in TMDL development. The nutrient data used for analysis in this report is attached in **Appendix C**. Data summaries of relevant water quality parameters for each nutrient impaired waterbody segment are provided in **Section 5.4.3**.

5.4 Water Quality Targets

TMDL water quality targets are numeric indicators used to evaluate attainment of water quality standards. They are discussed in **Section 4.0**. The following section presents nutrient water quality targets and compares those values with recently collected nutrient data in the Bitterroot River watershed using DEQ's draft assessment methodology (Suplee and Sada de Suplee, 2011). To be consistent with DEQ's draft assessment methodology, and because analytical methods have improved; only data from the past 10 years (2003–2012) are included in the review of existing data. Additionally, many of the nutrient samples collected before 2005 were analyzed for Total Kjeldahl Nitrogen (TKN), which DEQ has since replaced with Total Persulfate Nitrogen as the preferred analytical method for determining total nitrogen. TN has also replaced TKN as a preferred parameter for evaluating nitrogen impairment. It should be noted that DEQ Circular 12 includes both of these analytical methods as means of determining total nitrogen.

5.4.1 Nutrient Water Quality Standards

DEQ has developed base numeric criteria for nitrogen and phosphorus to reflect the intent of Montana's narrative standards requiring that state surface waters must be free from substances attributable to municipal, industrial, or agricultural practices or other discharges that produce nuisance conditions; create concentrations or combinations of material toxic or harmful to aquatic life; or create conditions that produce undesirable aquatic life [ARM 17.30.637(1)]. The state-approved base numeric criteria for TN and TP are in DEQ's Circular DEQ-12A, and are awaiting formal approval by EPA under the federal Clean Water Act. These numeric criteria are the basis for the nutrient TMDL targets consistent with EPA's TMDL development guidance (http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/strategy/) and federal regulations (40 Code of Federal Regulations (CFR) §131.11(a) & (b)).

5.4.2 Nutrient Target Values

Nutrient water quality targets include nutrient concentrations in surface waters and measures of benthic algae chlorophyll-*a* (a form of undesirable aquatic life at elevated concentrations). The target concentrations for nitrogen and phosphorus are established at levels believed to protect aquatic life and recreation. Since 2002, DEQ has conducted a number of studies in order to develop numeric criteria for nutrients (N and P forms). Nutrient criteria for TN and TP, and threshold concentrations for chlorophyll-*a*, are based on two factors: (1) the results of public perception surveys (Suplee et al., 2009) on what level of algae was perceived as undesirable and (2) the outcome of nutrient stressor-response studies that determine nutrient concentrations that will maintain algal growth below undesirable and harmful levels (Suplee et al., 2007; Suplee and Watson, 2013).

Nutrient targets for TN and TP, based on the numeric criteria in DEQ-12A, and chlorophyll-*a*, and ash-free dry mass (AFDM) target concentrations, based on Suplee and Watson (2013), are presented in **Table 5-2**. The NO_3+NO_2 target is based on research by DEQ (Suplee et al., 2007) and (Suplee, Michael W., personal communication 11/14/2013) and can also be found in **Table 5-2**. DEQ has determined that the values for NO_3+NO_2, TN, and TP provide an appropriate numeric translation of the applicable narrative nutrient water quality standards based on existing water quality data in the Bitterroot project area. The target values are based on the most sensitive uses; therefore, the nutrient TMDLs are protective of all designated uses.

Macroinvertebrates were also included in the nutrient target suite for streams in the Middle Rockies and Idaho Batholith Level III Ecoregions as a biometric indicator. For macroinvertebrates, the Hilsenhoff Biotic Index (HBI) score is used. The HBI value increases as the amount of pollution tolerant macroinvertebrates in a sample increases; the macroinvertebrate target is an HBI score equal to or less than 4.0 (Suplee and Sada de Suplee, 2011) (**Table 5-2**).

Because numeric nutrient chemistry is established to maintain algal levels below target chlorophyll-*a* concentrations and AFDM, target attainment applies and is evaluated during the summer growing season (July 1–September 30 for the Middle Rockies and Idaho Batholith Level III Ecoregions) when algal growth will most likely affect beneficial uses. Targets in this document are established specifically for nutrient TMDL development in the Bitterroot project area and may or may not apply to streams in other TMDL project areas.

Table 5-2. Nutrient Targets in the Bitterroot Project Area by Ecoregion

Parameter	Target Values	
	Middle Rockies (Level III)	Idaho Batholith (Level III)
Nitrate+Nitrite (NO_3+NO_2)	≤ 0.100 mg/L	≤ 0.100 mg/L
Total Nitrogen (TN)	≤ 0.300 mg/L	≤ 0.275 mg/L
Total Phosphorous (TP)	≤ 0.030 mg/L	≤ 0.025 mg/L
Chlorophyll-*a*	≤ 125 mg/m²	≤ 125 mg/m²
Ash-free Dry Mass (AFDM)	≤35 g/m2	≤35 g/m2
Hilsenhoff's Biotic Index (HBI)	<4.0	<4.0

There are three separate Level III ecoregions in the Bitterroot project area (**Figure 5-2**), but because the streams of concern are only in the Middle Rockies and Idaho Batholith ecoregions, the target values for those ecoregions are presented in **Table 5-2**. For Ambrose, Lick, Muddy Spring, North Burnt Fork, and Threemile Creeks, the Middle Rockies Level III Ecoregion targets were applied. The Idaho Batholith Level III Ecoregion includes parts or all of the drainages of Bass, Lick, North Fork Rye, Rye, and Sweathouse Creeks. After reviewing the hydrologic data for each individual basin, it was determined that the Idaho Batholith targets would be applied to Bass, North Fork Rye, Rye, and Sweathouse Creeks. North Fork Rye and Rye Creeks are nearly wholly contained in the Level III Idaho Batholith ecoregion. Bass and Sweathouse Creeks are gaining streams in the upper reaches, which encompass the Idaho Batholith Ecoregion and losing streams in the lower reaches (Middle Rockies Ecoregion). Lick Creek gains most of its flow in the lower reaches of the stream, so the Level III Middle Rockies Ecoregion targets were used.

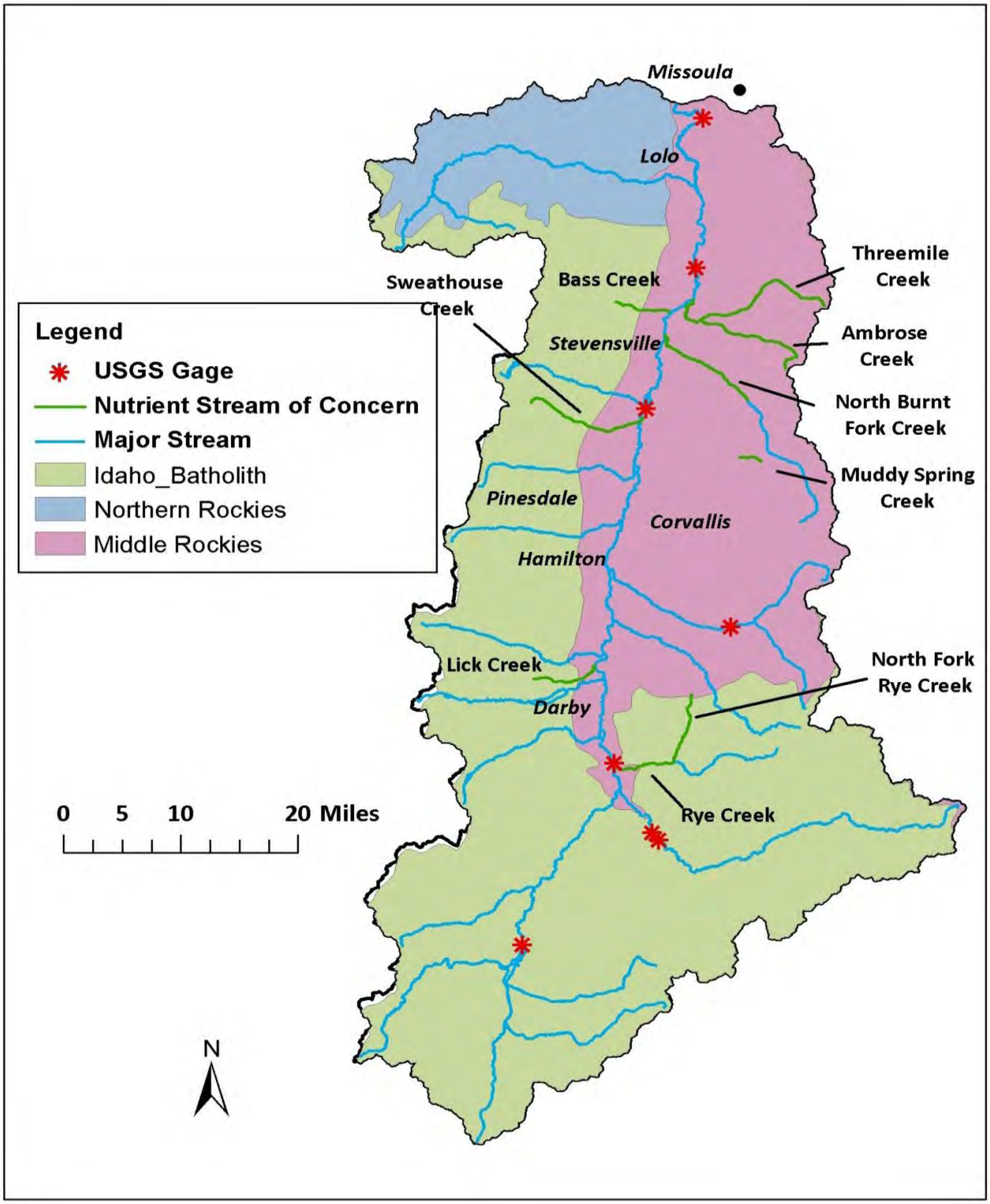


Figure 5-2. Level III ecoregions in the Bitterroot Project Area.

5.4.3 Existing Conditions and Comparison to Targets

DEQ evaluated nutrient target attainment by comparing existing water quality conditions with the water quality targets in **Tables 5-2** and **5-3**, using the methodology in DEQ's guidance document "2011 Assessment Methodology for Determining Wadeable Stream Impairment due to Excess Nitrogen and Phosphorus Levels" (Suplee and Sada de Suplee, 2011). For each waterbody segment, a data summary will be presented along with a comparison of existing data with targets, using the assessment methodology and a TMDL development determination. Because most of the impairment listings are based on older data, or were listed before numeric criteria were developed, each stream segment will be evaluated for impairment from NO_3+NO_2, TN, and TP using data collected within the past 10 years. TMDL development determinations depend on results of the data evaluation, and these updated impairment conclusions are captured in the 2014 303(d) List and associated 2014 Water Quality Integrated Report. Some streams in the Bitterroot project area lacked adequate data for a full assessment, in which case impairment listings remain unchanged. In these situations, the determination to develop a TMDL is based on the current listing status.

The assessment methodology uses two statistical tests (Exact Binomial Test and the One-Sample Student's T-test for the Mean) to evaluate water quality data for compliance with established target values. In general, water quality targets are not attained (a) when nutrient chemistry data have a target exceedance rate of >20% (Exact Binomial Test), (b) when the results of mean water quality nutrient chemistry exceed target values (Student T-test), or (c) when a single chlorophyll-*a* result exceeds benthic algal target concentrations (125 mg/m^2 or 35 g AFDM/m^2). In some cases, the chlorophyll-*a s*tandard operating procedure allows for a visual assessment where the collector determines that at all sampling transects, chlorophyll-*a* densities are less than 50 mg/m^2. In these cases, samples are not collected and the site is qualitatively assessed as having a chlorophyll-*a* density <50 mg/m^2. Where water chemistry and algae data do not provide a clear determination of impairment status, or when other limitations exist, the Hilsenhoff Biotic Metric (HBI) biometric is considered in further evaluating whether nutrient targets have been achieved, as directed by the assessment methodology. The HBI is a biometric based on tolerance values. A large number of macroinvertebrate taxa have been assigned a numeric value that represents the organism's tolerance to organic pollution (Barbour et al., 1999). HBI is then calculated as a weighted average tolerance value of all individuals in a sample (Suplee and Sada de Suplee, 2011). Higher index values indicate increasing tolerance to pollution.

Periphyton biometrics were developed by DEQ for Montana as an indicator of impairment. The exception to this use of diatoms is the Middle Rockies Level III ecoregion, for which there are no validated diatom increaser metrics. Periphyton data were not collected on in the Bitterroot project area as most of the impaired streams in the Bitterroot TMDL project are within the Middle Rockies Level III ecoregion.

Note: to ensure a higher degree of certainty for removing an impairment determination and making any new determination, the statistical tests are configured differently for an unlisted nutrient form than for a listed nutrient form, which may result in a different number of allowable exceedances for nutrients within a single stream segment. This helps assure that assessment reaches do not vacillate between listed and delisted status by the change in results from a single additional sample.

5.4.3.1 Ambrose Creek

Ambrose Creek flows 11.7 miles from the headwaters in the Sapphire Mountains on the east side of the Bitterroot Valley to its confluence with Threemile Creek. The assessment unit was first listed in 2000 as being impaired by TN and TP based on nutrient data. Newer data were evaluated and the results of the assessment concluded that the TN and TP remain causes of impairment to Ambrose Creek and the results are reflected in the 2014 Integrated Report. The outcome of the assessment is summarized below.

Summary nutrient data statistics and assessment method evaluation results for Ambrose Creek are provided in **Tables 5-3** and **5-4**, respectively. Eighteen NO_3+NO_2 samples were collected between 2003 and 2012; values ranged from <0.01 to 4.23 mg/L with seven samples exceeding the nutrient target of 0.10 mg/L. Thirteen TN samples were collected between 2007 and 2012; values ranged from 0.06 to 4.91 mg/L with nine samples exceeding the target of 0.300 mg/L. Eighteen TP samples were collected between 2003 and 2012; values ranged from 0.043 to 0.375 mg/L with all 18 samples exceeding the target of 0.030 mg/L.

Three chlorophyll-*a* samples and two ash-free dry mass (AFDM) samples were collected in 2012. The chlorophyll-*a* values ranged from 5.8 to 23.6 mg/m^2 with none exceeding the target of 125 mg/m^2. In addition, chlorophyll-*a* was visually estimated to be below 50 mg/m^2 at one site on Ambrose Creek in 2010. The AFDM values ranged from 5.44 to 6.31 g/m^2 with none exceeding the target of 35 g/m^2. There were two macroinvertebrate samples collected in 2005 and both samples were below the HBI target value of 4.0.

TN, NO_3+NO_2, and TP all failed both statistical tests with all TP samples exceeding the target concentration (**Table 5-4**). TN and TP TMDLs will be developed based on the results of the statistical tests, the overwhelming number of target exceedances, and the prior listing status. Because the NO_3+NO_2 impairment is reflected in the TN data, a TMDL for NO_3+NO_2 will not be developed but will be addressed by the TN TMDL.

Table 5-3. Nutrient Data Summary for Ambrose Creek

Nutrient Parameter	Sample Timeframe	n	Min[1]	Max	Median	80th percentile
NO_3+NO_2, mg/L	2003-2012	18	<0.01	4.23	0.055	0.283
TN, mg/L	2007-2012	13	0.06	4.91	0.520	0.756
TP, mg/L	2003-2012	18	0.043	0.375	0.150	0.195
Chlorophyll-*a*, mg/m2	2012	3[2]	5.8	23.6	13.4	18.5
AFDM, g/m2	2012	2	5.44	6.31	NA	NA
Macroinvertebrate HBI	2005	2	2.54	2.77	NA	NA

[1] Values proceeded by a "<" symbol are reporting limits for that parameter and the sample result was below the reporting limit. For statistical purposes, ½ the reporting limit was used to calculate the median and 80th percentile.
[2]One additional visual estimate sample of <50 mg/m^2 was not included in the summary statistics.

Table 5-4. Assessment Method Evaluation Results for Ambrose Creek

Nutrient Parameter	n	Target Value (mg/l)	Target Exceedances	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	TMDL Required?
NO_3+NO_2	18	0.100	7	**FAIL**	**FAIL**	PASS	PASS	PASS	NO
TN	13	0.300	9	**FAIL**	**FAIL**				**YES**
TP	18	0.030	18	**FAIL**	**FAIL**				**YES**

5.4.3.2 Bass Creek

Bass Creek originates at Bass Lake in the Bitterroot Mountains on the west side of the Bitterroot Valley, and flows approximately 10 miles to its confluence with the Bitterroot River. The assessment unit includes 5.1 miles of the stream from the Selway-Bitterroot Wilderness boundary to the mouth (un-named channel of the Bitterroot River). Bass Creek was first listed in 2006 as being impaired by TN based on nutrient data. Newer data were evaluated and the results of the assessment concluded that TN remains a cause of impairment and TP should be added as a cause of impairment to Bass Creek. The outcome of the Bass Creek assessment is reflected in the 2014 Integrated Report and is summarized below.

Summary nutrient data statistics and assessment method evaluation results for Bass Creek are provided in **Tables 5-5** and **5-6**, respectively. Thirteen NO_3+NO_2 samples were collected between 2004 and 2012; values ranged from <0.01 to 0.04 mg/L with zero samples exceeding the nutrient target of 0.10 mg/L. Twelve TN samples were collected between 2007 and 2012; values ranged from <0.05 to 0.81 mg/L with three samples exceeding the target of 0.275 mg/L. Fifteen TP samples were collected between 2004 and 2012; values ranged from <0.001 to 0.152 mg/L with four samples exceeding the target of 0.025 mg/L.

Three chlorophyll-*a* samples were collected in 2007 and 2012. Chlorophyll-*a* values ranged from 3.81 to 35.2 mg/m^2 with none exceeding the target of 125 mg/m^2. Two AFDM samples were collected in 2012. The AFDM values ranged from 16.5 to 22.0 g/m^2 with none exceeding the target of 35 g/m^2. There were three macroinvertebrate samples collected in 2004 and all of the samples were below the HBI target value of 4.0.

NO_3+NO_2 passed both statistical tests while TN and TP failed both statistical tests. Although the chlorophyll-*a* and AFDM did not exceed the targets, according to DEQ's assessment methodology if TN and TP exceed the targets and the exceedance rate, then results suggest that algal sampling may have missed peaks of benthic algal biomass. As a result of the assessment, TN and TP TMDLs will be developed. As the NO_3+NO_2 impairment is reflected in the TN data, a TMDL for NO_3+NO_2 will not be developed but will be addressed by the TN TMDL.

Table 5-5. Nutrient Data Summary for Bass Creek

Nutrient Parameter	Sample Timeframe	n	Min[1]	Max	Median	80th percentile
NO_3+NO_2, mg/L	2004-2012	13	<0.01	0.04	0.010	0.013
TN, mg/L	2007-2012	12	<0.05	0.81	0.255	0.316
TP, mg/L	2004-2012	15	<0.001	0.152	0.030	0.041
Chlorophyll-*a*, mg/m2	2007, 2012	3	3.81	35.2	31.9	33.9
AFDM, g/m2	2012	2	16.5	22.0	NA	NA
Macroinvertebrate HBI	2004	3	2.16	3.68	3.12	3.62

[1] Values proceeded by a "<" symbol are reporting limits for that parameter and the sample result was below the reporting limit. For statistical purposes, ½ the reporting limit was used to calculate the median and 80^{th} percentile.

Table 5-6. Assessment Method Evaluation Results for Bass Creek

Nutrient Parameter	n	Target Value (mg/l)	Target Exceedances	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	TMDL Required?
NO_3+NO_2	13	0.100	0	PASS	PASS				NO
TN	12	0.275	3	**FAIL**	**FAIL**	PASS	PASS	PASS	**YES**
TP	15	0.025	4	**FAIL**	**FAIL**				**YES**

5.4.3.3 Lick Creek

Lick Creek flows 6.4 miles from the headwaters in the Bitterroot Mountains on the west side of the Bitterroot Valley to its confluence with the Bitterroot River. Lick Creek was first listed in 2006 as being impaired by chlorophyll-*a*, TN, and TP based on nutrient and chlorophyll-*a* data. Newer data were evaluated and the results of the assessment concluded that TP remains a cause of impairment to Lick Creek, while TN has been removed as a cause of impairment. While no chlorophyll-*a* values exceeded the recommended nutrient criteria; it remains listed as a non-pollutant cause of impairment because nutrient impairment is still present in the waterbody segment. The outcome of the Lick Creek assessment is reflected in the 2014 Integrated Report and is summarized below.

Summary nutrient data statistics and assessment method evaluation results for Lick Creek are provided in **Tables 5-7** and **5-8**, respectively. Sixteen NO_3+NO_2 samples were collected between 2004 and 2012; values ranged from <0.005 to 0.04 mg/L with no samples exceeding the nutrient target of 0.10 mg/L. Fifteen TN samples were collected between 2007 and 2012; values ranged from <0.01 to 0.23 mg/L with no samples exceeding the target of 0.300 mg/L. Seventeen TP samples were collected between 2004 and 2012; values ranged from 0.015 to 0.043 mg/L with six samples exceeding the target of 0.030 mg/L.

Three chlorophyll-*a* samples were collected in 2012. The chlorophyll-*a* values ranged from 5.3 to 14.2 mg/m^2 with none exceeding the target of 125 mg/m^2. In addition, chlorophyll-*a* was visually estimated to be below 50 mg/m^2 at one site on Lick Creek in 2010. Three AFDM samples were collected in 2012.The AFDM values ranged from 3.60 to 4.26 g/m^2 with none exceeding the target of 35 g/m^2. There were two macroinvertebrate samples collected in 2004 and one sample did not meet the HBI target value of 4.0.

NO_3+NO_2 and TN passed both statistical tests while TP failed the binomial test and passed the T-test. Given the results of the statistical analyses, TN has been removed as a cause of impairment to Lick Creek; TP will remain a cause of impairment given the combined statistical analyses and macroinvertebrate HBI score. A TP TMDL will be developed for Lick Creek and will address the chlorophyll-*a* non-pollutant cause.

Table 5-7. Nutrient Data Summary for Lick Creek

Nutrient Parameter	Sample Timeframe	n	Min[1]	Max	Median	80th percentile
NO_3+NO_2, mg/L	2004-2012	16	<0.005	0.04	0.005	0.009
TN, mg/L	2007-2012	15	<0.01	0.23	0.060	0.132
TP, mg/L	2004-2012	17	0.014	0.043	0.023	0.035
Chlorophyll-*a*, mg/m2	2012	3[2]	5.3	14.2	5.90	10.9
AFDM, g/m2	2012	3	3.60	4.26	4.26	4.46
Macroinvertebrate HBI	2004	2	2.48	4.60	NA	NA

[1] Values proceeded by a "<" symbol are reporting limits for that parameter and the sample result was below the reporting limit. For statistical purposes, ½ the reporting limit was used to calculate the median and 80th percentile.
[2]One additional visual estimate sample of <50 mg/m^2 was not included in the summary statistics.

Table 5-8. Assessment Method Evaluation Results for Lick Creek

Nutrient Parameter	n	Target Value (mg/l)	Target Exceedances	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	TMDL Required?
NO_3+NO_2	16	0.100	0	PASS	PASS				NO
TN	15	0.300	0	PASS	PASS	PASS	PASS	**FAIL**	NO
TP	17	0.030	6	**FAIL**	PASS				**YES**

5.4.3.4 Muddy Spring Creek

Muddy Spring, a tributary to Gold Creek, begins in the Sapphire Mountains on the east side of the Bitterroot Valley and flows 2.0 miles to its confluence with Gold Creek. Muddy Spring Creek was first listed in 2006 as being impaired by $N0_3$+ $N0_2$ based on nutrient data. Newer data were evaluated and the results of the assessment concluded that $N0_3$+ $N0_2$ remains a cause of impairment to Muddy Spring Creek. The results of the Muddy Spring Creek assessment are reflected in the 2014 Integrated Report and are summarized below.

Summary nutrient data statistics and assessment method evaluation results for Muddy Spring Creek are provided in **Tables 5-9** and **5-10**, respectively. The stream was difficult to sample given its location and short length, so the data are limited. Four NO_3+NO_2 samples were collected in 2012; values ranged from 0.13 to 0.19 mg/L with all four samples exceeding the nutrient target of 0.10 mg/L. Four TN samples were collected in 2012; values ranged from 0.21 to 0.27 mg/L with no samples exceeding the target of 0.300 mg/L. Four TP samples were collected in 2012; values ranged from 0.037 to 0.051 mg/L with all four samples exceeding the target of 0.030 mg/L.

Two chlorophyll-*a* samples and two AFDM samples were collected in 2012. The chlorophyll-*a* values ranged from 6.4 to 23.4 mg/m^2 with none exceeding the target of 125 mg/m^2. The AFDM values ranged from 2.44 to 2.68 g/m^2 with none exceeding the target of 35 g/m^2. There were two macroinvertebrate samples collected in 2012 and both met the HBI target value of 4.0.

There were not enough data to conduct a full formal assessment of Muddy Spring Creek. However, all four samples exceeded the target concentration for $N0_3$+$N0_2$; therefore, it will remain a cause of impairment and a $N0_3$+ $N0_2$ TMDL will be developed.

Table 5-9. Nutrient Data Summary for Muddy Spring Creek

Nutrient Parameter	Sample Timeframe	n	Min	Max	Median	80th percentile
NO_3+NO_2, mg/L	2012	4	0.13	0.19	0.170	0.184
TN, mg/L	2012	4	0.21	0.27	0.240	0.252
TP, mg/L	2012	4	0.037	0.051	0.044	0.049
Chlorophyll-*a*, mg/m2	2012	2	6.4	23.4	NA	NA
AFDM, g/m2	2012	2	2.44	2.68	NA	NA
Macroinvertebrate HBI	2012	2	3.27	3.32	NA	NA

Table 5-10. Assessment Method Evaluation Results for Muddy Spring Creek

Nutrient Parameter	n	Target Value (mg/l)	Target Exceedances	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	TMDL Required?
NO_3+NO_2	4	0.100	4	NA	NA				**YES**
TN	4	0.300	0	NA	NA	PASS	PASS	PASS	NO
TP	4	0.030	4	NA	NA				NO

5.4.3.5 North Burnt Fork Creek

North Burnt Fork Creek begins in the Sapphire Mountains on the east side of the Bitterroot Valley. The assessment unit includes 10.9 miles of stream from its confluence with South Burnt Fork Creek to its mouth at the Bitterroot River. North Burnt Fork Creek was first listed in 2002 as being impaired for TN and TP based on nutrient data. Newer data were evaluated and the results of the assessment concluded that both TN and TP remain causes of impairment to North Burnt Fork Creek. The results of the North Burnt Fork Creek assessment are reflected in the 2014 Integrated Report and are summarized below.

Summary nutrient data statistics and assessment method evaluation results for North Burnt Fork Creek are provided in **Tables 5-11** and **5-12**, respectively. Twelve NO_3+NO_2 samples were collected between 2005 and 2012; values ranged from <0.005 to 0.040 mg/L with no samples exceeding the nutrient target of 0.10 mg/L. Nine TN samples were collected between 2007 and 2012; values ranged from 0.10 to 0.35 mg/L with one sample exceeding the target of 0.300 mg/L. Thirteen TP samples were collected between 2005 and 2012; values ranged from 0.020 to 0.065 mg/L with eight samples exceeding the target of 0.030 mg/L.

Three chlorophyll-*a* samples and two AFDM samples were collected in 2010 and 2012. The chlorophyll-*a* values ranged from <0.10 to 41.4 mg/m^2 with none exceeding the target of 125 mg/m^2. The AFDM values ranged from 22.0 to 27.0 g/m^2 with none exceeding the target of 35 g/m^2. There were three macroinvertebrate samples collected in 2005 and two samples exceeded the HBI target value of 4.0.

Although there was not the sufficient number of samples to meet the minimum sample size to assess TN, there was one target exceedance that failed the binomial test under minimal sample size conditions. Because North Burnt Fork Creek was previously listed, only 1 exceedance out of 13 samples for TN and TP would result in a failure of the binomial test. One of nine samples exceeded the target concentration for TN; therefore, TN remains a cause of impairment. $N0_3$+$N0_2$ passed both statistical tests, while TP failed both statistical tests. Given the results of the statistical analyses and macroinvertebrate HBI score, the assessment supports the previous listings; therefore, TN and TP TMDLs will be developed for North Burnt Fork Creek.

Table 5-11. Nutrient Data Summary for North Burnt Fork Creek

Nutrient Parameter	Sample Timeframe	n	Min[1]	Max	Median	80th percentile
NO_3+NO_2, mg/L	2005-2012	12	<0.005	0.04	0.005	0.007
TN, mg/L	2007-2012	9	0.10	0.35	0.190	0.252
TP, mg/L	2005-2012	13	0.020	0.065	0.036	0.050
Chlorophyll-*a*, mg/m2	2010, 2012	3	<0.10	41.4	NA	NA
AFDM, g/m2	2010, 2012	2	22.0	27.0	NA	NA
Macroinvertebrate HBI	2005	3	3.23	6.05	4.60	5.43

[1] Values proceeded by a "<" symbol are reporting limits for that parameter and the sample result was below the reporting limit. For statistical purposes, ½ the reporting limit was used to calculate the median and 80th percentile.

Table 5-12. Assessment Method Evaluation Results for North Burnt Fork Creek

Nutrient Parameter	n	Target Value (mg/l)	Target Exceedances	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	TMDL Required?
NO_3+NO_2	12	0.100	0	PASS	PASS	PASS	PASS	**FAIL**	NO
TN	9	0.300	1	**FAIL** [1]	NA				**YES**
TP	13	0.030	8	**FAIL**	**FAIL**				**YES**

[1] Although the sample size was insufficient for the binomial test, one exceedance of the target would fail the binomial if the minimum sample size was met.

5.4.3.6 North Fork Rye Creek

North Fork Rye Creek begins in the Sapphire Mountains on the east side of the Bitterroot Valley and flows 7.1 miles from the headwaters to its confluence with Rye Creek. North Fork Rye Creek was first listed in 2000 as impaired for TN and TP based on nutrient data. Newer data were evaluated and the results of the assessment concluded that both TN and TP remain causes of impairment to North Fork Rye Creek. The results of the North Fork Rye Creek assessment are reflected in the 2014 Integrated Report and are summarized below.

Summary nutrient data statistics and assessment method evaluation results for North Fork Rye Creek are provided in **Tables 5-13** and **5-14**, respectively. Fifteen NO_3+NO_2 samples were collected between 2006 and 2012; values ranged from <0.005 to 0.209 mg/L with two samples exceeding the nutrient target of 0.10 mg/L. Thirteen TN samples were collected between 2007 and 2012; values ranged from 0.08 to 0.41 mg/L with three samples exceeding the target of 0.275 mg/L. Fifteen TP samples were collected between 2006 and 2012; values ranged from 0.015 to 0.055 mg/L with five samples exceeding the target of 0.025 mg/L.

Three chlorophyll-*a* samples and two AFDM samples were collected in 2007 and 2012. The chlorophyll-*a* values ranged from 19.3 to 84.8 mg/m^2 with none exceeding the target of 125 mg/m^2. The AFDM values ranged from 11.2 to 38.5 g/m^2 with one sample exceeding the target of 35 g/m^2. There were two macroinvertebrate samples collected in 2005 and both samples exceeded the HBI target value of 4.0.

NO_3+NO_2, TN, and TP all failed the binomial statistical test and TN and TP both failed the T-test as well. The assessment supports the current TN and TP listings on North Fork Rye Creek and TMDLs will be developed for both. As the NO_3+NO_2 impairment is reflected in the TN data, a TMDL for NO_3+NO_2 will not be developed but will be addressed by the TN TMDL.

Table 5-13. Nutrient Data Summary for North Fork Rye Creek

Nutrient Parameter	Sample Timeframe	n	Min[1]	Max	Median	80th percentile
NO_3+NO_2, mg/L	2006-2012	15	<0.005	0.209	0.006	0.054
TN, mg/L	2007-2012	13	0.08	0.41	0.150	0.268
TP, mg/L	2006-2012	15	0.015	0.055	0.022	0.035
Chlorophyll-*a*, mg/m2	2007, 2012	3	19.3	84.8	35.1	64.9
AFDM, g/m2	2012	2	11.2	38.5	NA	NA
Macroinvertebrate HBI	2005	2	4.52	4.59	NA	NA

[1] Values proceeded by a "<" symbol are reporting limits for that parameter and the sample result was below the reporting limit. For statistical purposes, ½ the reporting limit was used to calculate the median and 80th percentile.

Table 5-14. Assessment Method Evaluation Results for North Fork Rye Creek

Nutrient Parameter	n	Target Value (mg/l)	Target Exceedances	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	TMDL Required?
NO_3+NO_2	15	0.100	2	**FAIL**	PASS	PASS	**FAIL**	**FAIL**	NO
TN	13	0.275	3	**FAIL**	PASS				**YES**
TP	15	0.025	5	**FAIL**	**FAIL**				**YES**

5.4.3.7 Rye Creek

Rye Creek begins in the Sapphire Mountains on the east side of the Bitterroot Valley and flows for 17.5 miles before reaching its confluence with the Bitterroot River. The assessment unit includes 6.0 miles of the stream from North Fork Rye Creek to the mouth (Bitterroot River). Rye Creek was first listed in 2002 as being impaired by TN and TP based on nutrient data. Newer data were evaluated and the results of the assessment concluded that both TN and TP remain causes of impairment to Rye Creek. The results of the Rye Creek assessment are reflected in the 2014 Integrated Report and are summarized below.

Summary nutrient data statistics and assessment method evaluation results for Rye Creek are provided in **Tables 5-15** and **5-16**, respectively. Eight NO_3+NO_2 samples were collected between 2006 and 2012; values ranged from <0.010 to 0.084 mg/L with no samples exceeding the nutrient target of 0.10 mg/L. Eight TN samples were collected between 2007 and 2012; values ranged from 0.10 to 0.37 mg/L with two samples exceeding the target of 0.275 mg/L. Nine TP samples were collected between 2006 and 2012; values ranged from 0.006 to 0.051 mg/L with four samples exceeding the target of 0.025 mg/L.

Two chlorophyll-*a* samples were collected in 2010. The chlorophyll-*a* values ranged from 20.6 to 35.6 mg/m^2 with none exceeding the target of 125 mg/m^2. In addition, chlorophyll-*a* was visually estimated to be below 50 mg/m^2 at one site on Rye Creek in 2010. Two AFDM samples were collected in 2010. The AFDM values ranged from 15.1 to 28.7 g/m^2 with none exceeding the target of 35 g/m^2. There was one macroinvertebrate sample collected in 2005 that did not exceed the HBI target value of 4.0.

Additional data were collected from three monitoring locations on Rye Creek above the assessment unit end point that were not included in the water quality assessment, but are included in the source assessment. Five NO_3+NO_2 samples were collected between 2006 and 2010; values ranged from <0.01 to 0.027 mg/L with no samples exceeding the target of 0.100 mg/L. Four TN samples were collected in 2007 and 2010; values ranged from 0.15 to 0.24 mg/L with no samples exceeding the target of 0.275 mg/L. Five TP samples were collected between 2006 and 2010; values ranged from 0.053 to 0.105 mg/L with all five samples exceeding the target of 0.025 mg/L. In addition, a chlorophyll-*a* and AFDM sample were collected in 2010. The chlorophyll-*a* value was 16.9 mg/m^2 and did not exceed the target of 125 mg/m^2. The AFDM value was 14.9 g/m^2 and did not exceed the target of 35 g/m^2. There was one macroinvertebrate sample collected in 2005 that exceeded the HBI target value of 4.0.

Although there were not the sufficient number of samples to meet the minimum sample size to assess $N0_3$+$N0_2$, TN, and TP, there were sufficient TN and TP target exceedances that failed the binomial test under minimal sample size conditions. Because Rye Creek was previously listed, only 1 exceedance out of 13 samples for TN or TP would result in a failure of the binomial test. Two of eight samples exceeded the target concentration for TN and four of nine samples exceeded the target concentration for TP; therefore, TN and TP will remain as causes of impairment and TN and TP and TMDLs will be developed.

Table 5-15. Nutrient Data Summary for Rye Creek

Nutrient Parameter	Sample Timeframe	n	Min[1]	Max	Median	80th percentile
NO_3+NO_2, mg/L	2006-2012	8	<0.01	0.084	0.008	0.032
TN, mg/L	2007-2012	8	0.10	0.37	0.180	0.244
TP, mg/L	2006-2012	9	0.006	0.051	0.023	0.045
Chlorophyll-*a*, mg/m2	2010	2	20.6	35.6	NA	NA
AFDM, g/m2	2010	2	15.1	28.7	NA	NA
Macroinvertebrate HBI	2005	1	NA	3.92	NA	NA

[1] Values proceeded by a "<" symbol are reporting limits for that parameter and the sample result was below the reporting limit. For statistical purposes, ½ the reporting limit was used to calculate the median and 80th percentile.

Table 5-16. Assessment Method Evaluation Results for Rye Creek

Nutrient Parameter	n	Target Value (mg/l)	Target Exceedances	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	TMDL Required?
NO_3+NO_2	8	0.100	0	PASS	PASS				NO
TN	8	0.275	2	**FAIL**[1]	PASS	PASS	PASS	PASS	**YES**
TP	9	0.025	4	**FAIL**[1]	**FAIL**				**YES**

[1] Although the sample size was insufficient for the binomial test, one exceedance of the target would fail the binomial if the minimum sample size was met.

5.4.3.8 Sweathouse Creek

Sweathouse Creek begins in the Bitterroot Mountains on the west side of the Bitterroot Valley and flows 11.6 miles from the headwaters to its confluence with the Bitterroot River. Sweathouse Creek was first listed in 2002 as being impaired by TP. Newer data were evaluated and the results of the assessment concluded that TP remains a cause of impairment to Sweathouse Creek. The results of the Sweathouse Creek assessment are reflected in the 2014 Integrated Report and are summarized below.

Summary nutrient data statistics and assessment method evaluation results for Sweathouse Creek are provided in **Tables 5-17** and **5-18**, respectively. Thirteen NO_3+NO_2 samples were collected between 2006 and 2012; values ranged from <0.01 to 0.07 mg/L with no samples exceeding the nutrient target of 0.10 mg/L. Fourteen TN samples were collected between 2007 and 2012; values ranged from 0.048 to 0.500 mg/L with two samples exceeding the target of 0.275 mg/L. Sixteen TP samples were collected between 2006 and 2012; values ranged from<0.001 to 0.058 mg/L with six samples exceeding the target of 0.025 mg/L.

Two chlorophyll-*a* samples were collected in 2010 and 2012. The chlorophyll-*a* values ranged from 13.2 to 16.7 mg/m^2 with none exceeding the target of 125 mg/m^2. In addition, chlorophyll-*a* was visually estimated to be below 50 mg/m^2 at one site on Sweathouse Creek in 2010. Two AFDM samples were collected in 2010 and 2012. The AFDM values ranged from 4.55 to 5.38 g/m^2 with none exceeding the target of 35 g/m^2. There were three macroinvertebrate samples collected in 2005 and 2012 and no samples exceeded the HBI target value of 4.0.

$N0_3$+$N0_2$ and TN passed both statistical tests, while TP failed both the binomial test and the T-test. Although the chlorophyll-*a* and AFDM did not exceed the targets, according to DEQ's assessment methodology if TN and TP exceed the targets and the exceedance rate, then results suggest that algal sampling may have missed peaks of benthic algal biomass. Given the results of the statistical analysis and that there is a current TP listing on the stream; a TP TMDL will be developed for Sweathouse Creek.

Table 5-17. Nutrient Data Summary for Sweathouse Creek

Nutrient Parameter	Sample Timeframe	n	Min[1]	Max	Median	80th percentile
NO_3+NO_2, mg/L	2006-2012	13	<0.01	0.07	0.022	0.036
TN, mg/L	2007-2012	14	0.048	0.500	0.145	0.238
TP, mg/L	2006-2012	16	<0.005	0.058	0.012	0.049
Chlorophyll-*a*, mg/m2	2010, 2012	2[2]	13.2	16.7	NA	NA
AFDM, g/m2	2010, 2012	2	4.55	5.38	NA	NA
Macroinvertebrate HBI	2005, 2012	3	2.74	3.40	2.82	3.17

[1]Values proceeded by a "<" symbol are reporting limits for that parameter and the sample result was below the reporting limit. For statistical purposes, ½ the reporting limit was used to calculate the median and 80th percentile.
[2]One additional visual estimate sample of <50 mg/m^2 was not included in the summary statistics.

Table 5-18. Assessment Method Evaluation Results for Sweathouse Creek

Nutrient Parameter	n	Target Value (mg/l)	Target Exceedances	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	TMDL Required?
NO_3+NO_2	13	0.100	0	PASS	PASS	PASS	PASS	PASS	NO
TN	14	0.275	2	PASS	PASS				NO
TP	16	0.025	6	**FAIL**	**FAIL**				**YES**

5.4.3.9 Threemile Creek

Threemile Creek begins in the Sapphire Mountains on the east side of the Bitterroot Valley and flows 18.0 miles from the headwaters to its confluence with the Bitterroot River. Threemile Creek was first listed in 1996 as being impaired by $N0_3$+ $N0_2$ and TP. Newer data were evaluated and the results of the assessment concluded that $N0_3$+ $N0_2$ and TP remain as causes of impairment; in addition, TN was added as a cause of impairment to Threemile Creek. The results of the Threemile Creek assessment are reflected in the 2014 Integrated Report and are summarized below.

Summary nutrient data statistics and assessment method evaluation results for Threemile Creek are provided in **Tables 5-19** and **5-20**, respectively. Ten NO_3+NO_2 samples were collected between 2003 and 2010; values ranged from 0.018 to 0.837 mg/L with six samples exceeding the nutrient target of 0.10 mg/L. Seven TN samples were collected between 2007 and 2010; values ranged from <0.05 to 1.20 mg/L with four samples exceeding the target of 0.300 mg/L. Eleven TP samples were collected between 2003 and 2010; values ranged from 0.041 to 0.144 mg/L with all 11 samples exceeding the target of 0.030 mg/L.

One chlorophyll-*a* sample and one AFDM sample were collected in 2010. The chlorophyll-*a* value was 7.5 mg/m^2, which did not exceed the target of 125 mg/m^2. In addition, chlorophyll-*a* was visually estimated to be below 50 mg/m^2 at two sites on Threemile Creek in 2010. The AFDM value was 3.22 g/m^2, which did not exceed the target of 35 g/m^2. There were three macroinvertebrate samples collected in 2005 and no samples exceeded the HBI target value of 4.0.

Chlorophyll-*a* and AFDM did not exceed the targets, but according to DEQ's assessment methodology if TN and TP exceed the targets and the exceedance rate, then results suggest that algal sampling may have missed peaks of benthic algal biomass. Although there were not a sufficient number of samples to meet the minimum sample size for assessment, $N0_3$+$N0_2$, TN, and TP all failed both statistical tests since more than half of the samples exceeded the water quality target. Because Threemile Creek was previously listed, only 1 exceedance out of 13 samples for $N0_3$+$N0_2$, TN, or TP would result in a failure of the binomial test. Six of 10 samples exceeded the target concentration for $N0_3$+$N0_2$, 4 of 7 samples exceeded the target concentration for TN, and all samples exceeded the target concentration for TP; therefore, $N0_3$+$N0_2$, TN, and TP remain as causes of impairment and TN and TP and TMDLs will be developed on Threemile Creek. As the NO_3+NO_2 impairment is reflected in the TN data, a TMDL for NO_3+NO_2 will not be developed but will be addressed by the TN TMDL.

Table 5-19. Nutrient Data Summary for Threemile Creek

Nutrient Parameter	Sample Timeframe	n	Min[1]	Max	Median	80th percentile
NO_3+NO_2, mg/L	2003-2010	10	0.018	0.837	0.355	0.486
TN, mg/L	2007-2010	7	<0.05	1.20	0.510	0.766
TP, mg/L	2003-2010	11	0.041	0.144	0.104	0.140

Table 5-19. Nutrient Data Summary for Threemile Creek

Nutrient Parameter	Sample Timeframe	n	Min[1]	Max	Median	80th percentile
Chlorophyll-*a*, mg/m2	2010	1[2]	NA	7.5	NA	NA
AFDM, g/m2	2010	1	NA	3.22	NA	NA
Macroinvertebrate HBI	2005	3	1.40	3.86	3.48	3.71

[1] Values proceeded by a “<” symbol are reporting limits for that parameter and the sample result was below the reporting limit. For statistical purposes, ½ the reporting limit was used to calculate the median and 80th percentile.
[2]Two additional visual estimate samples of <50 mg/m^2 were not included in the summary statistics.

Table 5-20. Assessment Method Evaluation Results for Threemile Creek

Nutrient Parameter	n	Target Value (mg/l)	Target Exceedances	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	TMDL Required?
NO_3+NO_2	10	0.100	6	**FAIL[1]**	**FAIL**	PASS	PASS	PASS	NO
TN	7	0.300	4	**FAIL[1]**	**FAIL**				**YES**
TP	11	0.030	11	**FAIL[1]**	**FAIL**				**YES**

[1] Although the sample size was insufficient for the binomial test, one exceedance of the target would fail the binomial if the minimum sample size was met.

5.4.3.10 Miller Creek

Miller Creek begins in the Sapphire Mountains on the east side of the Bitterroot Valley and flows for 18.3 miles from the headwaters to its confluence with the Bitterroot River. Miller Creek was first listed in 2006 as being impaired for $N0_3$+ $N0_2$, chlorophyll-*a*, and TP nutrient impairments. Newer data were evaluated and the results of the assessment concluded that nutrients are not a cause of impairment; therefore, the stream will be de-listed for all of the nutrient causes. The results of the Miller Creek assessment will not be reflected until the 2016 Integrated Report, but the results of the assessment are summarized below.

Summary nutrient data statistics and assessment method evaluation results for Miller Creek are provided in **Tables 5-21** and **5-22**, respectively. Thirteen NO_3+NO_2 samples were collected between 2004 and 2012; values ranged from <0.005 to 0.09 mg/L with no samples exceeding the nutrient target of 0.30 mg/L. Thirteen TN samples were collected between 2004 and 2012; values ranged from <0.05 to 0.30 mg/L with no samples exceeding the target of 0.300 mg/L. Thirteen TP samples were collected between 2004 and 2012; values ranged from 0.007 to 0.023 mg/L with no samples exceeding the target of 0.030 mg/L.

Two chlorophyll-*a* samples and two ash-free dry mass (AFDM) samples were collected in 2012. The chlorophyll-*a* values ranged from 10.6 to 22.3 mg/m^2 with none exceeding the target of 125 mg/m^2. In addition, chlorophyll-*a* was visually estimated to be below 50 mg/m^2 at one site on Miller Creek in 2010. The AFDM values ranged from 6.23 to 6.30 g/m^2 with none exceeding the target of 35 g/m^2. There were three macroinvertebrate samples collected from 2004-2005 and one sample did not meet the HBI target value of 4.0.

TN, NO_3+NO_2, and TP passed both statistical tests (**Table 5-22**) so NO_3+NO_2, chlorophyll-*a*, and TP will be removed as causes of impairment to Miller Creek, which will be reflected in the 2016 Integrated Report. As a result, no nutrient TMDLs will be developed for Miller Creek.

Table 5-21. Nutrient Data Summary for Miller Creek

Nutrient Parameter	Sample Timeframe	n	Min[1]	Max	Median	80th percentile
NO_3+NO_2, mg/L	2004-2012	13	<0.005	0.09	0.007	0.050
TN, mg/L	2004-2012	13	<0.05	0.30	0.070	0.166
TP, mg/L	2004-2010	13	0.007	0.023	0.021	0.023
Chlorophyll-*a*, mg/m2	2012	2[2]	10.6	22.3	NA	NA
AFDM, g/m2	2012	2	6.23	6.30	NA	NA
Macroinvertebrate HBI	2004-2005	3	1.98	4.70	3.14	4.07

[1] Values proceeded by a "<" symbol are reporting limits for that parameter and the sample result was below the reporting limit. For statistical purposes, ½ the reporting limit was used to calculate the median and 80^{th} percentile.
[2]An additional visual estimate sample of <50 mg/m^2 was not included in the summary statistics.

Table 5-22. Assessment Method Evaluation Results for Miller Creek

Nutrient Parameter	n	Target Value (mg/l)	Target Exceedances	Binomial Test Result	T-test Result	Chl-*a* Test Result	AFDM Test Result	Macro Test Result	TMDL Required?
NO_3+NO_2	13	0.100	0	PASS	PASS				NO
TN	13	0.300	0	PASS	PASS	PASS	PASS	**FAIL**	NO
TP	13	0.030	0	PASS	PASS				NO

5.4.4 Nutrient TMDL Development Summary

Table 5-23 summarizes the updated impairment and TMDL development determinations for the waterbodies of concern identified in **Section 5.3**. Fifteen TMDLs will be developed for TN and TP, addressing a total of 16 nutrient causes of impairment and 1 chlorophyll-*a* (non-pollutant) impairment cause. TN will be used as a surrogate TMDL for NO_3+NO_2, with the exception of Muddy Spring Creek, for which a NO_3+NO_2 TMDL will be developed since it is the only nutrient impairment cause for that waterbody.

The updated impairment listings are reflected in the 2014 Water Quality Integrated Report and associated 2014 303(d) List, with the exception of the Miller Creek delisting, which will be reflected in the 2016 Water Quality Integrated report.

Table 5-23. Summary of Nutrient TMDL Development Determinations

Stream Segment	Waterbody ID	2014 303(d) Nutrient Impairment(s)	TMDLs Prepared
AMBROSE CREEK, headwaters to mouth (Threemile Creek)	MT76H004_120	TN, TP	TN, TP
BASS CREEK, Selway-Bitterroot Wilderness boundary to mouth (unnamed channel of Bitterroot River), T9N R20W S3	MT76H004_010	TN, TP	TN, TP
LICK CREEK, headwaters to mouth (Bitterroot River)	MT76H004_170	TP, Chlorophyll-*a*[1]	TP
MILLER CREEK, headwaters to mouth (Bitterroot River)	MT76H004_130	N03+ N02, TN, TP	None
MUDDY SPRING CREEK, headwaters to mouth (Gold Creek) T7N R19W S2	MT76H004_180	$N0_3$+ $N0_2$	$N0_3$+ $N0_2$
NORTH BURNT FORK CREEK, confluence with South Burnt Fork Creek to Mouth (Bitterroot River)	MT76H004_200	TN, TP	TN, TP
NORTH FORK RYE CREEK, headwaters to mouth (Rye Creek-Bitterroot River, South of Darby)	MT76H004_160	TN, TP	TN, TP
RYE CREEK, North Fork to mouth (Bitterroot River)	MT76H004_190	TN, TP	TN, TP

Table 5-23. Summary of Nutrient TMDL Development Determinations

Stream Segment	Waterbody ID	2014 303(d) Nutrient Impairment(s)	TMDLs Prepared
SWEATHOUSE CREEK, headwaters to mouth (Bitterroot River)	MT76H004_210	TP	TP
THREEMILE CREEK, headwaters to mouth (Bitterroot River)	MT76H004_140	$N0_3$+ $N0_2$, TN, TP	TN, TP

[1] Non-pollutant; remains an impairment cause and is addressed via nutrient TMDLs.

5.5 Source Assessment, TMDL, and Allocation Approaches

This section summarizes the approach used for the source assessment, TMDLs, and allocations and then presents the source assessment results, TMDL, allocations, and estimated reductions necessary to meet water quality targets for each of the nine nutrient impaired streams.

5.5.1 Source Assessment Approach

Source characterization and assessment to determine the major sources in each of the nutrient impaired waterbodies was conducted by using monitoring data collected from the Bitterroot project area from 2003 to 2012, and by using aerial photos, Geographic Information System (GIS) analysis, field work, phone interviews, and literature reviews. Assessment of existing nutrient (i.e., NO_3+NO_2, TN and TP) sources is needed to understand load allocations and load reductions. Source characterization links nutrient sources, nutrient loading to streams, and water quality response, and supports the formulation of the allocation portion of the TMDL.

Land use in the Bitterroot project area primarily consists of agriculture (irrigated cropland and livestock grazing), silviculture (timber harvest and forest roads), historical mining, and residential development, including subsurface wastewater disposal and treatment. There are no permitted point sources in the nine waterbodies described in this document. Therefore, nutrient loading is coming from two source types: 1) natural sources derived from airborne deposition, vegetation, soils, and geologic weathering; and 2) human-caused nonpoint sources dispersed across the landscape (e.g., agriculture, residential development, and timber harvest). These sources may include a variety of discrete and diffuse pollutant inputs that have differing pathways to a waterbody. Ideally sampling is conducted in a way that allows identification of these pathways.

The most recent water quality sampling data used to determine existing nutrient water quality conditions and potential sources in the Bitterroot project area were collected between 2003 and 2012. These data were collected to 1) evaluate attainment of water quality targets, 2) develop TMDLs, and 3) assess load contributions from nutrient sources. Data used to conduct these analyses are publicly available at: http://www.epa.gov/storet/dw_home.html. Box plots were used to display nutrient concentrations measured from the impaired streams and helped to define the magnitude and location of nutrient loading and potential sources. In descriptive statistics, box plots are a convenient way of graphically depicting groups of numerical data through their five number summaries. Box plots depict the smallest observation (sample minimum), 25^{th} percentile, median, 75^{th} percentile, and the largest observation (sample maximum). Box plots display differences between the data without making any assumptions of the underlying statistical distribution of the data. The spacing between the different parts of the box indicates the degree of dispersion and skewness in data and identifies outliers. When sample data used in boxplots were below reporting limits, half the reporting limit was used.

5.5.1.1 Nonpoint Sources of Nutrients

Nutrient inputs into the streams in the Bitterroot project area come from several nonpoint sources (i.e., diffuse sources that cannot easily be pinpointed). DEQ identified the following source categories that contribute nutrients in the project area:

- Agriculture (irrigated cropping and pasture/rangeland/forest grazing)
- Subsurface wastewater disposal and treatment (individual and community septic systems)
- Residential development
- Silviculture (timber harvest and forest roads)
- Mining
- Natural background

Agriculture

There are several possible mechanisms for the transport of nutrients from agricultural land to surface water during the growing season. The potential pathways include: the effect of grazing on vegetative health and its ability to uptake nutrients and minimize erosion in upland and riparian areas, breakdown of excrement and loading via surface and subsurface pathways, delivery from grazed forest and rangeland during the growing season, transport of fertilizer applied in late spring via overland flow and groundwater, and the increased mobility of phosphorus caused by irrigation-related saturation of soils in pastures (Green and Kauffman, 1989).

Irrigated and Dryland Cropping

Cropping in the Bitterroot project area is primarily irrigated production of alfalfa hay and pasture/hay, with smaller acreages of irrigated and dryland production of other crops including: potatoes, corn, winter wheat, sod/grass, and small grains. Irrigated lands are usually in continuous production and have annual soil disturbance and fertilizer inputs. Dryland cropping may have fallow periods of 16 to 22 months, depending on site characteristics and landowner management. Nutrient pathways include overland runoff, deep percolation to groundwater, and shallow groundwater flow, all of which transport nutrients off site.

Livestock Grazing

Grazing on private rangeland and pastures is common in the Bitterroot project area. Cattle are allowed to roam and graze and in some areas along the valley bottoms during the growing season. Some cattle have been observed on small acreage lots that are fenced. Horses may also be allowed to roam and graze though they have been mostly observed on small acreage lots that are fenced. Pastures are managed for hay production during the summer and for grazing during the fall and spring. Hay pastures are thickly vegetated in the summer; less so in the fall through spring. The winter grazing period is long (October–May), and trampling and feeding further reduces biomass when it is already low. Commercial fertilizers are used infrequently in the watershed, and naturally applied cattle manure is a more significant source of nutrients. Cattle manure occurs in higher quantities on pasture ground from October through May because of higher cattle density than that found on range and forested areas.

Rangeland differs from pasture in that rangeland has much less biomass than other land uses, and therefore contributes fewer nutrients from biomass decay. However, grazing impacts do factor in and manure deposition can result in significant nutrient contribution to an impaired waterbody via tributaries. Rangeland is grazed during the summer months (June-October) in the watershed.

Livestock grazing on rangeland located on federal lands is another potential nutrient source in some of the nutrient impaired waterbodies in the Bitterroot project area. The grazing allotments by federal leases in the Bitterroot project area are limited to <4 months during the summer/early fall period, beginning generally in early- to mid-June and extending to late-September or mid-October. Grazing allotment data were collected from the USFS and the average number of Animal Unit Months (AUMs) from 2003-2013 for the total allotment was provided. One AUM is equivalent to the forage consumed by one cow/calf pair for one month. Within the past 10 years, some grazing allotments were not grazed in all years, so the average AUMs were calculated to include grazed and ungrazed years. For the purposes of this compilation, where allotments spanned multiple watershed boundaries, the density of AUMs was estimated as a percentage of the allotment area within the applicable watershed boundaries (**Table 5-24**). It is recognized that this is a coarse assumption, and the densities are an estimate.

Table 5-24. Summary of Grazing Allotments on USFS Lands in the Bitterroot River Watershed

Watershed	Percentage of Total Allotment Within Watershed (%)	Area of Grazing Allotment in Watershed (ac)	Average Number of AUMs/year from 2003-2013[1]	Years of No Grazing	Density of AUMs in Watershed (AUMs/ac)
Ambrose Creek	100	1,677	26	2007, 2009, 2011,2012	0.02
Bass Creek	7	22	100	-	0.02
Lick Creek	31	2,319	75	-	0.003
Muddy Spring Creek	32	837	53	2008 - 2013	0.007
Rye Creek	9	1,317	200	-	0.001
Sweathouse Creek	100	1,015	16	-	0.02

[1]Average calculated to include grazed and ungrazed years

Subsurface Wastewater Treatment and Disposal
Discharge of septic effluent from individual septic systems and community septic systems in the Bitterroot project area, which discharge to groundwater, may all contribute to nutrient loading in streams depending on a combination of discharge, soils, and distance from the downgradient waterbody. Septic systems, even when operating as designed, can contribute nutrients to surface water through subsurface pathways.

Residential Development
Significant growth has occurred in the Bitterroot project area, as the population of the valley has grown (with population growth as high as 44% in the 1990s) and the number of homes and other development has increased. Developed areas contribute nutrients to the watershed by runoff from impervious surfaces, deposition by machines/automobiles, application of fertilizers, and increased irrigation on lawns. This increased development has also resulted in a significant increase in the use of subsurface wastewater and treatment disposal.

Silviculture (Timber Harvest and Forest Roads)
A large portion of the Bitterroot project area is on forested lands administered by the Bitterroot National Forest. Silviculture practices inevitably cause some measure of downstream effects that may or may not be significant over time. Changes in land cover will alter the rate at which water evapotranspires and thus the water balance; in that the distribution of water between base flow and runoff will change. Disturbances of the ground surface will also disrupt the hydrological cycle. The combination of these changes can alter water yield, peak flows, and water quality (Jacobson, 2004). Changes in biomass uptake and soil conditions will affect the nutrient cycle. Elevated nitrate

concentrations result from increased leaching from the soil as mineralization is enhanced. This increase generally only lasts up to 2 or 3 years before returning to pre-harvest levels (Feller and Kimmins, 1984; Likens et al., 1978; Martin and Harr, 1989). Nutrient uptake by biomass is also greatly reduced after timber harvest, leaving more nutrients available for runoff. Loading from silviculture is not estimated in this document because timber harvest occurs in specific locations within a watershed that differ from one year to the next. In addition, the effect of timber harvest on instream nutrient levels is short term and would be difficult to model as a general effect. In lieu of loading estimates, water quality data were examined in relationship to harvest records to determine if timber harvest is having an identifiable effect.

A coarse assessment of recent timber operations (since 2003) was made based on USFS data and Montana Spatial Data Infrastructure (MSDI) geospatial land cover data layer for the watersheds of interest in the Bitterroot project area that have nutrient impaired waterbodies. These data were used to better understand recent operations by scale and location in comparison with available water chemistry data. It is used where appropriate to inform the source assessment.

Mining

Surface water quality can be degraded by releases of contaminants from mine waste material or from co-mingling with acid mine drainage from mine adits. Nutrient impacts from mining can result from the use of blasting (e.g., TNT), which introduces nitrate, and the use of cyanide, which introduces TN. Concentration of potential contaminants depends on whether or not these methods were used, the timing of when mining has taken place, mechanism of chemical release, streamflow, and water chemistry.

The Bitterroot project area's mining history is described in DEQ's Abandoned Mine Lands historical narratives (Montana Department of Environmental Quality, 2009a). Mining never became as prominent in the Bitterroot Valley as in other watersheds in western Montana. Abandoned and inactive mines are present at a relatively low density. Placer mines were not significantly productive, and neither were subsequent lode mines. Abandoned or inactive placer mines are located in the Ambrose, Threemile, Sweathouse, and Rye Creek drainages while abandoned or inactive lode mines are present in the Rye and Bass Creek drainages. Water quality data were examined in relationship to specific historic mine locations to determine if mining was having an identifiable effect on nutrient loading.

Natural Background

Load allocations for natural background sources in all impaired segments are based on median concentration values from reference sites in either the Middle Rockies or the Idaho Batholith Level III Ecoregions, as applicable, during the July 1 to September 30 growing season. For the Middle Rockies Ecoregion, these values are TN = 0.095 mg/L, TP = 0.01 mg/L (Suplee and Watson, 2013), and NO_3+NO_2 = 0.02 mg/L (Suplee et al., 2007). For the Northern Rockies Ecoregion, these values are TN = 0.070 mg/L, TP = 0.006 mg/ L (Suplee and Watson, 2013) and NO_3+NO_2 = 0.012 mg/L (Suplee et al., 2007). Reference sites were chosen to represent stream conditions where human activities may be present but do not negatively harm stream uses. The effects of natural events such as flooding, fire, and beetle kill may be captured at these sites. Natural background loads are calculated by multiplying the median reference concentration by the measured median growing season streamflow.

5.5.2 TMDL and Allocation Approach

Loading estimates and load allocations are established for the summer growing season time period and are based on observed water quality data and flow conditions measured during this time period.

5.5.2.1 TMDL Equation

Nutrient TMDLs have been developed for the nutrient causes identified for each waterbody in **Table 5-23**. Because streamflow varies seasonally, TMDLs are not expressed as a static value, but as an equation of the appropriate target multiplied by flow as shown in **Equation 5**. TMDL calculations for NO_3+NO_2, TN, and TP are based on the following formula:

Equation 5: TMDL (lbs/day) = (X) (Y) (5.4)

*X = water quality target in mg/L (**Table 5-2**)*
Y = median streamflow in cubic feet per second (cfs)
5.4 = conversion factor

As flow increases, the allowable load (TMDL) increases as shown by the TP TMDL example in **Figure 5-3**. Like the water quality targets, the TMDLs are applied only to the summer growing season (July 1st through Sept 30th).

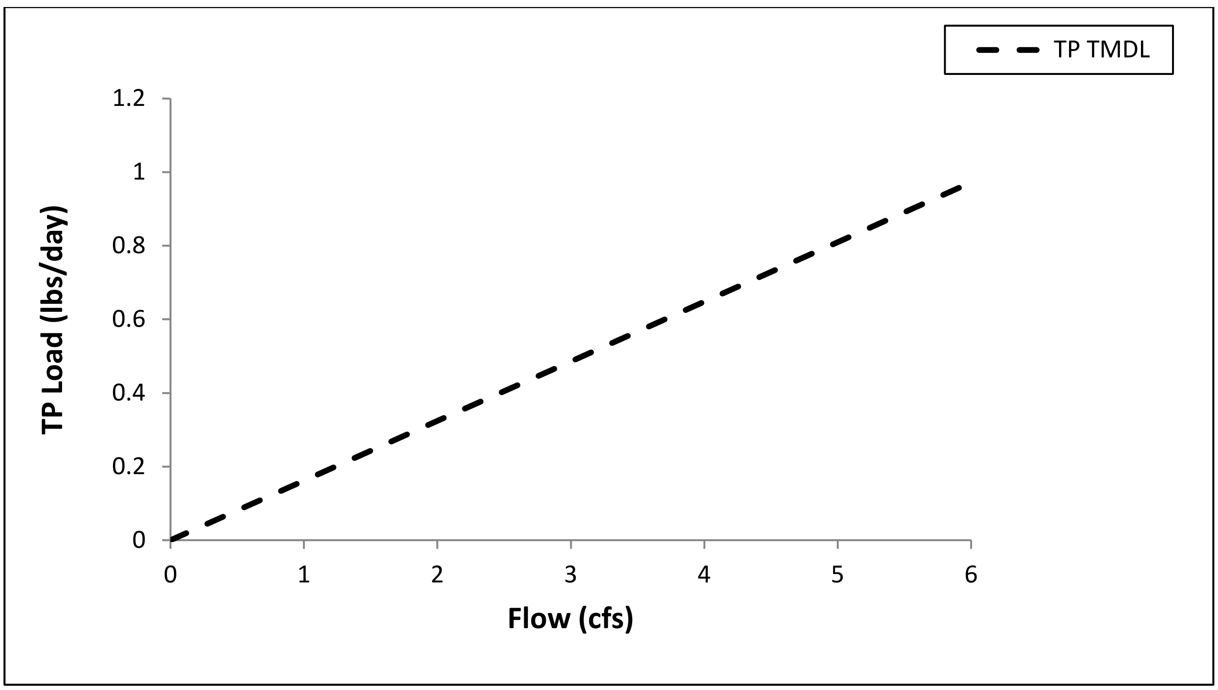


Figure 5-3. Example TMDL for TP for streamflows ranging from 0 to 6 cfs

Approach to TMDL Allocations

As discussed in **Section 4.0**, the NO_3+NO_2, TN, and TP TMDLs for applicable impaired waterbodies consists of the sum of load allocations (LAs) to individual source categories (**Tables 5-25** and **5-26**). Since all sources are nonpoint, the TMDL for each stream are broken into a load allocation to natural background and a composite load allocation to all human-caused nonpoint sources (**Equation 6**). In the absence of individual wasteload allocations and an explicit margin of safety, the TMDLs for NO_3+NO_2, TN, and TP in each waterbody are calculated as follows:

Equation 6: $TMDL = LA_{NB} + LA_H$

LA_{NB} = Load Allocation to natural background sources

LA_H = Load Allocation to human-caused nonpoint sources

Table 5-25. Nitrate and Total Nitrogen Source Categories and Descriptions for the Bitterroot Project Area

Source Category	Source Descriptions
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute nitrogen to nearby waterbodies
Nonpoint Sources (Livestock, Agriculture, Urban, and/or Timber Harvest)	• septic • domestic animal waste • fertilizer • loss of riparian and wetland vegetation along streambanks • limited nutrient uptake due to loss of overstory • runoff from exposed rock containing natural background nitrate • residual chemicals left over from mining practices • residential development

Table 5-26. Total Phosphorus Source Categories and Descriptions for the Bitterroot Project Area

Source Category	Load Allocation Descriptions
Natural Background	• soils and local geology • natural vegetative decay • wet and dry airborne deposition • wild animal waste • natural biochemical processes that contribute phosphorus to nearby waterbodies
Nonpoint Sources (Livestock, Agriculture, Urban, and/or Timber Harvest)	• septic • domestic animal waste • fertilizer • loss of riparian and wetland vegetation along streambanks • limited nutrient uptake due to loss of overstory • runoff from exposed rock containing natural background phosphorus

Natural Background Allocation

LAs for natural background sources in all applicable impaired segments are based on median concentration values from reference sites in the applicable Level III Ecoregions during the growing season (**Table 5-27**) as described in Suplee et al., (2008) and Suplee and Watson (2013). Reference sites were chosen to represent stream conditions where human activities may be present but do not negatively harm stream uses. The effects of natural events such as flooding, fire, and beetle kill may be captured at these sites.

Table 5-27. Median Concentration

Level II Ecoregion	Growing Season	Nitrate (mg/L)	TN (mg/L)	TP (mg/L)
Middle Rockies	July 1 to September 30	0.02	0.095	0.010
Idaho Batholith	July 1 to September 30	0.012	0.070	0.006

Natural background loads are calculated by multiplying the median reference concentration by the measured median growing season streamflow. The natural background load is calculated as follows:

Equation 7: LA_{NB} = (X) (Y) (5.4)

LA_{NB} = Load Allocation to natural background sources in lbs/day

*X = natural background concentration in mg/L (***Table 5-27***)*

Y = streamflow in cfs (median from the applicable stream)

5.4 = conversion factor

Allocations for Human-Caused Nonpoint Sources

The LA to human-caused nonpoint sources is calculated as the difference between the allowable daily load (TMDL) and the natural background load:

Equation 8: LA_H = TMDL – LA_{NB}

LA_H = Load Allocation to human-caused nonpoint sources

This equation will be used for all nutrient TMDLs in the Bitterroot project area.

5.5.2.2 Example Total Existing Load

To estimate an example total existing loading for the purpose of estimating a required load reduction, the following equation will be used:

Equation 9: Total Existing Load (lbs/day) = (X) (Y) (5.4)

X = measured concentration in mg/L (median of exceedances from the applicable stream)

Y = streamflow in cfs (median from the applicable stream)

5.4 = conversion factor

Only the median of the concentrations that exceeded the target will be used to determine the total existing load since concentrations greater than the target indicate that the TMDL is being exceeded and reductions are necessary.

5.5.2.3 Total Range and Median Load Reductions

Figures portraying the load reductions necessary to meet the nutrients targets are shown for each waterbody segment requiring (a) TMDL(s) in **Section 5.6**. Because flow data were absent for some of the water quality samples, these reductions were calculated using all measured nutrient concentrations that exceeded the target concentration. Any time concentration exceeds a target, the corresponding load, even if flow is not measured, exceeds the TMDL since the TMDL equation is based on concentration multiplied by the flow. Loads greater than the TMDL require reductions, so percent reductions in TN loads are the same as percent reductions in TN concentrations. **Equation 10** was used to calculate all load reductions:

Equation 10: Load Reduction = (1 - (Target Conc. /Measured Conc.))*100

Target Conc. = target concentration in mg/L

Measured Conc. = measured nutrient concentration in mg/L

Only concentrations that exceeded the target will be used to determine load reductions since concentrations greater than the target require indicate that the TMDL is being exceeded and reductions are necessary. Concentrations that are below the target are meeting the TMDL and do not require load reductions.

5.6 Source Assessments, TMDLs, and Allocations for Each Stream

The below sections describe the most significant natural and human-caused sources in more detail, establish TMDLs and composite LAs to identified sources, provide nutrient loading estimates for natural, and human-caused source categories to nutrient-impaired stream segments, and estimate reductions necessary to meet water quality targets for the following streams:

- Threemile Creek
- Ambrose Creek
- Bass Creek
- North Burnt Fork Creek
- Muddy Spring Creek
- Sweathouse Creek
- Lick Creek
- North Fork Rye Creek
- Rye Creek

The total existing loads are used to estimate load reductions by comparing them to the allowable (TMDL) load and computing a required percent reduction to meet the TMDL. These load reduction estimates can be complicated by nutrient uptake within the stream. The number of NO_3+NO_2, TN, and/or TP target exceedances, or the extent by which they exceed a target, can be masked by this nutrient uptake. No load reductions are given for natural background allocations; therefore all necessary load reductions apply to the nonpoint sources within each watershed.

The source assessments, TMDLs, and allocations for the streams of interest are discussed in order from downstream to upstream along the Bitterroot project area since two of the impaired streams, Ambrose and North Fork Rye Creek, are tributaries to impaired streams (Threemile and Rye Creeks, respectively).

5.6.1 Threemile Creek

Threemile Creek begins in the Sapphire Mountains on the east side of the Bitterroot Valley and flows 18.0 miles from the headwaters to its confluence with the Bitterroot River. Ambrose Creek, which is also listed as impaired for nutrients, is the largest tributary to Threemile Creek. Approximately 12 miles of the creek flows through private lands.

5.6.1.1 Assessment of Water Quality Results

The source assessment for Threemile Creek consists of an evaluation of NO_3+NO_2, TN, and TP concentrations, followed by an estimation of the most significant human-caused sources of nutrients. **Figure 5-4** presents the approximate locations of data pertinent to the source assessment in the Threemile Creek watershed.

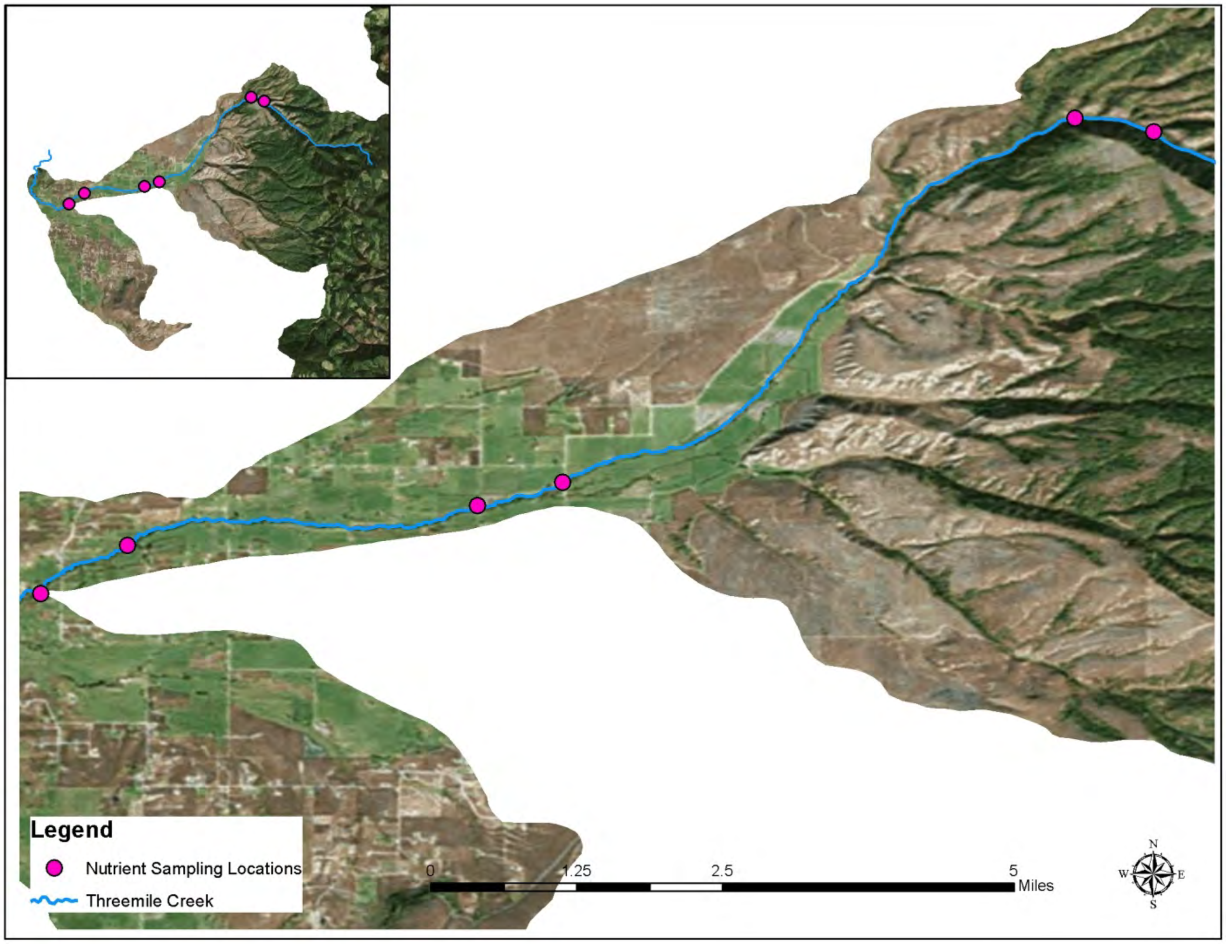


Figure 5-4. Threemile Creek Watershed with Water Quality Sampling Locations

It should be noted, that no data that were collected below the Ambrose Creek confluence were used for assessments. Near the mouth, Threemile Creek enters the Lee Metcalf National Wildlife Refuge, a wetland habitat for migratory birds. This complex of wetlands makes it difficult to discern the stream features and according to National Hydrography Dataset imagery, there are no digitized streams in this area. Data from monitoring stations at the Lee Metcalf National Wildlife Refuge and near the mouth were not used because they were not on the defined AU.

Nitrate + Nitrite

DEQ and Tri-State Water Quality Council (TSWQC) collected water quality samples for NO_3+NO_2 from Threemile Creek during the growing season between 2003 and 2010 (**Section 5.4.3.9, Table 5-19**). Out of 10 total samples, 6 exceeded the NO_3+NO_2 target of 0.100 mg/L. The upstream sites in the forested areas did not exceed the NO_3+NO_2 target. All six of the exceedances occurred downstream of the Grayhorse Creek confluence and the NO_3+NO_2 concentrations generally increase in a downstream direction to the Ambrose Creek confluence. The sampling location at the confluence of Threemile Creek and Ambrose Creek had the highest measured NO_3+NO_2 concentrations. Although data collected from monitoring stations at the Lee Metcalf Wildlife Refuge and near the mouth were not used, two out of seven samples collected from monitoring stations in these areas exceeded the target. **Figure 5-5** presents summary statistics for NO_3+NO_2 concentrations at sampling sites in Threemile Creek.

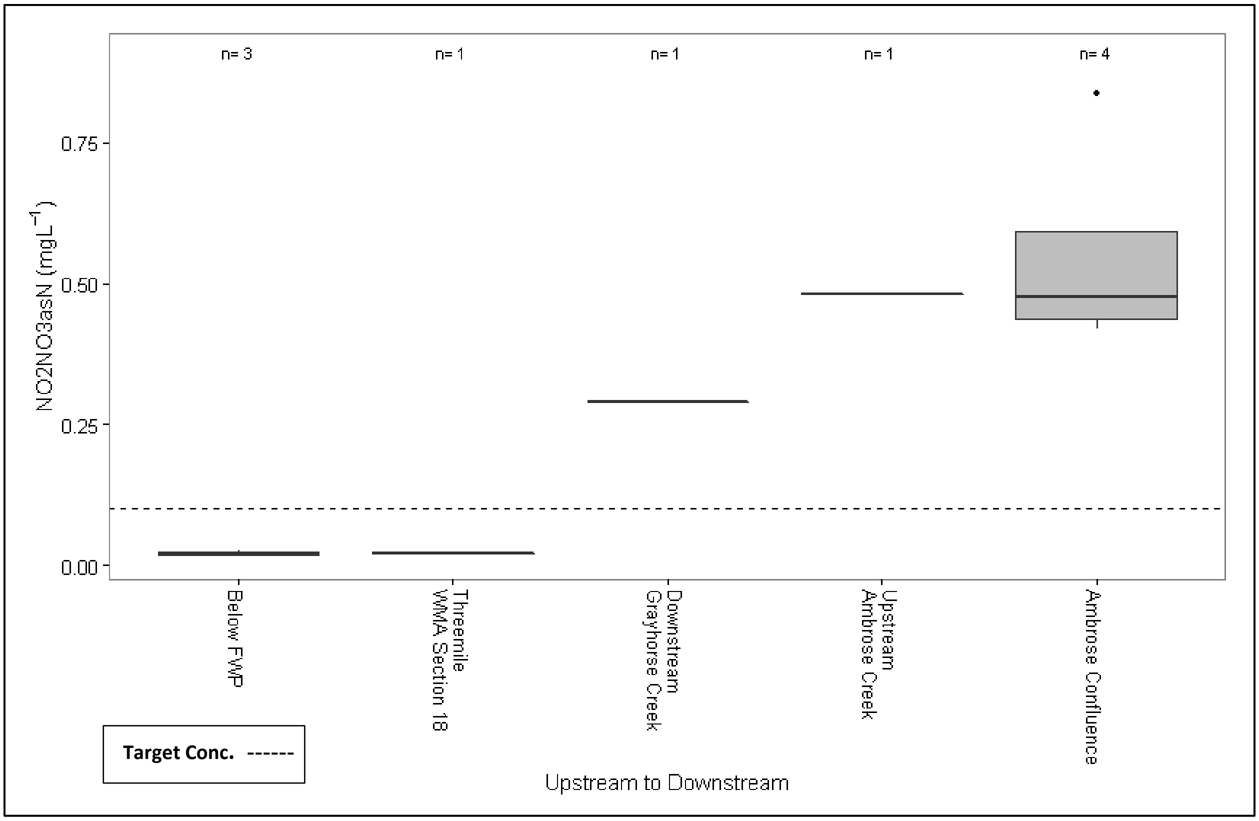


Figure 5-5. Boxplots of NO_3+NO_2 Concentrations in Threemile Creek (2003-2010)

Total Nitrogen

DEQ and TSWQC collected water quality samples for TN from Threemile Creek during the growing season between 2007 and 2010 (**Section 5.4.3.9, Table 5-19**). Out of seven total samples, four exceeded the TN target of 0.300 mg/L. The exceedances began downstream of the Grayhorse Creek confluence and the TN concentrations generally increase in a downstream direction to the Ambrose Creek confluence. The sampling location at the confluence of Threemile Creek and Ambrose Creek had the highest measured TN concentrations, with one sample concentration greater than 16 times the target concentration. The median concentration of TN of Ambrose Creek (which is also impaired for TN) near the confluence with Threemile Creek, is 0.745 mg/L, nearly 2.5 times the target concentration. This load is a significant source of TN for Threemile Creek. Although data collected from monitoring stations at the Lee Metcalf Wildlife Refuge and near the mouth were not used, three out of five samples collected from monitoring stations in these areas exceeded the target. **Figure 5-6** presents summary statistics for TN concentrations at sampling sites in Threemile Creek.

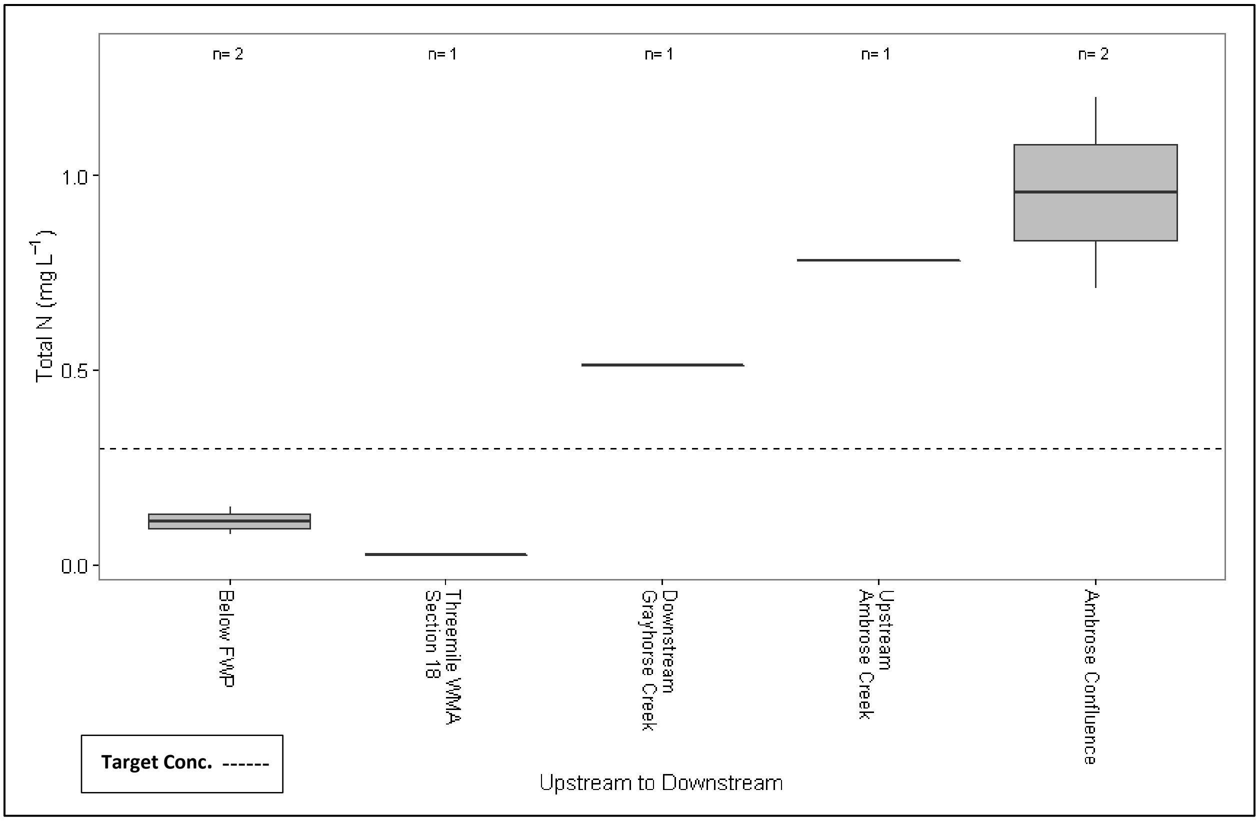


Figure 5-6. Boxplots of TN Concentrations in Threemile Creek (2007-2010)

Total Phosphorus

DEQ and TSWQC collected water quality samples for TP from Threemile Creek during the growing season between 2003 and 2010 (**Section 5.4.3.9, Table 5-19**). Out of 11 total samples, all exceeded the TP target of 0.03 mg/L. With the exception of the monitoring location downstream of the Grayhorse Creek confluence, the TP concentrations generally increased in a downstream direction to the Ambrose Creek confluence. Although the upstream TP concentrations near the USFS boundary exceeded the target, the downstream concentrations significantly increase by almost three times starting at the Threemile Road monitoring location. The median concentration of TP of Ambrose Creek (which is also impaired for TP) near the confluence with Threemile Creek, is 0.176 mg/L, nearly six times the target concentration. This load is a significant source of TP for Threemile Creek. Although data collected from monitoring stations at the Lee Metcalf Wildlife Refuge and near the mouth were not used, seven out of seven samples collected from monitoring stations in these areas exceeded the target. **Figure 5-7** presents summary statistics for TP concentrations at sampling sites in Threemile Creek.

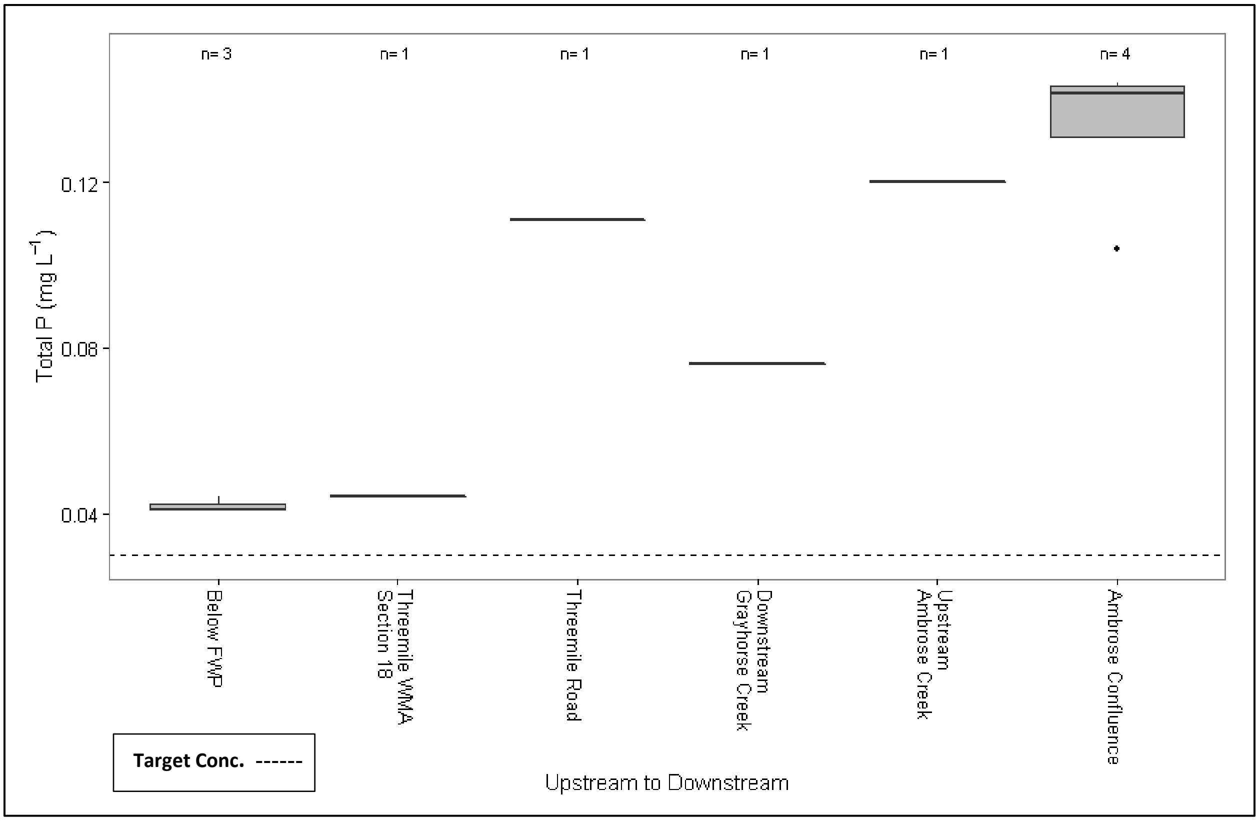


Figure 5-7. Boxplots of TP Concentrations in Threemile Creek (2003-2010)

5.6.1.2 Source Assessment

The Threemile Creek watershed includes forests, open grasslands and shrubs, pastures, and agricultural lands. The Threemile Creek watershed contains private and public forest land with only a small percentage of its total area administered by the Bitterroot National Forest. A larger percentage of the public lands include 6,049 acres of the Montana Fish, Wildlife and Parks administered Threemile Wildlife Management Area. The majority of the land in the lower reaches of the watershed is privately-owned and mostly agricultural (hay and pasture) with some residential development.

Excess nutrients in Threemile Creek have been noted as a problem for several decades. In 1997-1998, Ravalli County performed a study of nonpoint nutrient issues in the Bitterroot River watershed, which included Threemile Creek (Hooten, 1999). In 2002 and 2003, TSWQC conducted an extensive watershed assessment of Threemile Creek as part of a larger watershed assessment of the Ambrose-Threemile Creek watershed (McDowell and Rokosch, 2005). The data from both studies demonstrated that nutrient concentrations in Ambrose and Threemile Creeks tended to be high in comparison to other streams in the Bitterroot River watershed.

A sediment TMDL for Threemile Creek was completed in 2011 (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011a). As part of sediment TMDL development, DEQ performed a stream assessment at one site along Threemile Creek in 2007. The assessment reach was located on private land in the lower watershed where historic grazing and agriculture have given way to rural-residential development. The field assessment crew noted that the stream was entrenched with extensive streambank erosion, bare ground, and exposed banks in the survey reach. In addition, ongoing horse grazing was observed at the site and there were lawns encroaching on the channel margin along most of the reach. An assessment of riparian condition and near-stream land uses that were rated as fair or poor condition (67% of the streambank) were in areas dominated by agriculture and near-stream roads. Historic assessment records indicate that the problems leading to heavy sediment loads are subdivisions of land with small pasture units, large livestock concentrations, and riparian area grazing. The land use activities that are increasing sediment supplies to Threemile Creek are also likely linked to increased nutrient supplies.

Potential human sources that could contribute TP and TN to Threemile Creek are agriculture (crops, grazing in riparian or streamside zones, livestock confinement areas), urban development, septic, silvicultural activities, and historic mining; based on the summary statistics of the data, the majority of the nutrients originate in the valley rangeland and agricultural areas, which indicate that the primary land uses and most likely significant nutrient sources in the Threemile Creek watershed are agriculture and septic. Each of the potential human sources is discussed below, followed by an analysis of the sources.

Agriculture

Agriculture is the primary land use in the lower foothill and valley areas of Threemile Creek and a significant source of nutrients in the watershed, as evidenced by the data presented in **Figures 5.5 - 5.7**, where the elevated nutrient concentrations occur. Upper Threemile Creek drains the Threemile Wildlife Management Area managed by Montana Fish, Wildlife and Parks. Although there are no grazing allotments on the USFS land, much of the dryland pasture terrain below the National Forest is occupied by several large ranches used for beef cattle production (McDowell and Rokosch, 2005). Downgradient of the lower foothill rangeland areas, the valley portion of the watershed is used extensively for irrigated agriculture, including hay/alfalfa production with some small grains and sod, although there is an increasing number of small acreage pasture units and semi-rural residential subdivisions in this part of the watershed.

Nutrient loads from irrigations can come directly from ditch/channel intersections and indirectly from irrigation application and subsequent discharge to the stream channel via groundwater recharge and overland runoff. The Bitter Root Irrigation District (BRID) canal and Supply Ditch are the two primary sources of irrigation water on the eastern side of the Bitterroot valley. The BRID canal runs along the foothills of the Sapphire Mountains before crossing Threemile Creek at about river mile 8. According to the TSWQC study, the BRID does not directly contribute significant nutrient loads to the creek based on nutrient sampling that occurred in 2002 and 2003 above and below the Threemile Creek and BRID intersection. The input above the BRID system is rangeland so agricultural input from irrigated crops would be downgradient from the canal system. The Supply Ditch is located just above the Eastside Highway on the lower reach of Threemile Creek. Based on previous monitoring by TSWQC and the data collected by DEQ, the high loads of nutrients are occurring upstream of the Supply Ditch diversion, in areas of significant agricultural activity. Based on conversations with the irrigation managers for the BRID and Supply Ditch and analysis of the intersections, the inter-basin nutrient loads transferred to the systems are insignificant. However, including livestock influence, these inter-basin water transfers may contribute flow and a nutrient load indirectly to the irrigated portion of Threemile Creek through groundwater recharge and/or overland flow from flood irrigation.

Silviculture

Approximately 42% of the Threemile Creek watershed is forested. The forested upper watershed appears to contribute little to the excess nutrient load to Threemile Creek (McDowell and Rokosch, 2005) and TN in the forested reaches is generally below natural background. Although phosphorus in the forested reaches is approximately four times greater than natural background, the upper reaches are only a minor contribution of the nutrient load as evidenced by the summary statistics data.

An analysis of aerial imagery and geospatial land cover data shows parcels of land with recently burned and recently harvested forest in the northern-most portion of the watershed. In 2003, the Cooney Ridge Complex forest fire burned approximately 25,000 acres, with a small portion of the area burning in the upper northeast portion of the Threemile Creek watershed (near the headwaters). According to geospatial information provided by the USFS, there have not been any recent forest management/harvest activities on the USFS administered lands in the past 10 years. Montana Spatial Data Infrastructure (MSDI) land cover data for areas in the northern and north-eastern part of the watershed, administered by the USFS or owned by a private logging company, shows that timber harvest has occurred and a network of unpaved forestry roads are present. Forest Road 640 runs along much of the stream channel and is in relatively close proximity in some places. However, there exists a substantial riparian buffer between the road and the channel in most places and this road is not thought to be a substantial contributor of nutrients. The harvested areas and forestry roads may contribute sediment loads to the watershed via erosion, but the silvicultural activities are likely only a minor contributor of nutrient loads to the creek.

Subsurface Wastewater Treatment and Disposal

According to DEQ information, there are numerous individual septic systems in the Threemile Creek watershed. All of the individual septic systems are concentrated in the valley area, in the downstream part of the watershed, and in some places the septic density is over 100 septic units per square mile. There are a number of systems within close proximity (<100 ft) to the stream. These systems are likely part of the total nutrient loads into the creek, and are likely a more important contributor of nitrogen than phosphorus.

Residential Development

The Threemile Creek watershed has experienced increased residential development in the past 25 years and the semi-rural and suburban subdivision development is concentrated in the lower reaches of the creek. The developed land cover is interspersed with agricultural land and many of the residential areas have lawns that are likely irrigated and fertilized. Along a majority of the lower reach where the residential development is concentrated, there appears to be adequate riparian buffer, so residential development is likely only a minor contributor of nutrient loads into the creek via irrigation and fertilizer from lawns.

Mining

Minor placer and lode mining occurred in the Threemile Mining District and according to DEQ and Montana Bureau of Mines and Geology (MBMG) databases, there are six abandoned mines listed in the watershed. One placer mine, Threemile Mine, is located downstream of the Threemile Wildlife Management Area near the channel of Threemile Creek. Upstream of the Threemile Mine in the upper drainage of Threemile Creek are the other two placer mines, both aptly named Placer Mine. These abandoned gold mines are located in close proximity to the channel of Threemile Creek. Two lode mines, the Cleveland Mine (a former silver, lead, zinc and copper mine) and the Lucky Star Claim Mine are both located in the upper Threemile Creek watershed and are not in close proximity to the Threemile Creek channel.

Placer mining probably involved disturbance of the streamside area and the streambed itself, and evidence of this early placer mining can still be seen in the upper Threemile Creek (McDowell and

Rokosch, 2005). Little is known about the history of any of these abandoned mines, but the Cleveland Mine processed ore in an arrastra and there are no records of production.

As the NO_3 + NO_2 and TN concentrations are well below targets in the most upstream sampling locations, the historic mining activities do not provide a clear linkage as a source of nutrients in Threemile Creek.

5.6.1.3 NO_3 + NO_2 TMDL Surrogate

Because nitrate is a component of TN, and because the loading sources and methods to reduce loading sources of NO_3 + NO_2 and TN are essentially the same, the below TMDL for TN is a surrogate TMDL for NO_3 + NO_2 in Threemile Creek. As a result, existing NO_3 + NO_2 loading requires reductions consistent with the TN TMDL and the composite load allocation for NO_3 + NO_2 would apply to the same source categories as the TN composite load allocation.

5.6.1.4 TN TMDL, Allocations, and Current Loading

The TMDL for TN is based on **Equation 5** and the TMDL allocations are based on **Equation 6.** The value of the TN TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. The following example TN TMDL for Threemile Creek uses **Equation 5** with the median measured flow from all sites during 2007-2010 sampling (7.02 cfs):

TMDL = (0.300 mg/L) (7.02 cfs) (5.4) = 11.37 lbs/day

Equation 7 is the basis for the natural background load allocation for TN. To continue with the example at a flow of 7.02 cfs, this allocation is as follows:

LA_{NB} = (0.095 mg/L) (7.02 cfs) (5.4) = 3.60 lbs/day

Using **Equation 8**, the human-caused TN load allocation at 7.02 cfs can be calculated:

LA_H = 11.37 lbs/day – 3.60 lbs/day = 7.77 lbs/day

An example total existing load is based on **Equation 9**, and is calculated as follows using the median of TN target exceedance values measured from Threemile Creek from 2007-2010 (0.745 mg/L) and the median measured flow of 7.02 cfs:

Total Existing Load = (0.745 mg/L) (7.02 cfs) (5.4) = 28.24 lbs/day

The portion of the total existing load attributed to human sources is 24.64 lbs/day, which is determined by subtracting out the 3.60 lbs/day background load. This 24.64 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-28 contains the results for the example TN TMDL, LAs, and current loading. In addition, it contains an example percent reduction to the human-caused LA required to meet the water quality target for TN. At the median growing season flow of 7.02 cfs, and the median of measured TN target exceedance values, the current loading in Threemile Creek is greater than the TMDL. Under these example conditions, a 68% reduction of human-caused TN loads, which results in an overall 60% reduction of TN in Threemile Creek, would result in the TMDL being met. The source assessment of the

Threemile Creek watershed indicates that agriculture is the most likely source of TN in Threemile Creek; load reductions should focus on limiting and controlling TN loading from this source. Meeting LAs for Threemile Creek may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 9.4.1**.

Table 5-28. Threemile Creek TN Example TMDL, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction
Natural Background	3.60	3.60	0%
Human-caused (primarily agriculture)	7.77	24.64	68%
	TMDL = 11.37	**Total = 28.24**	**Total = 60%**

[1]Based on a median growing season flow of 7.02 cfs

Figure 5-8 shows the percent reductions for TN loads measured in Threemile Creek from 2007-2010. Because flow data were absent for some of the water quality samples, reductions were calculated for any sample where the measured TN concentrations were above the target. Any time concentration exceeds the target, the corresponding load, even if flow is not measured, exceeds the TMDL since the TMDL equation is based on concentration multiplied by the flow. Loads greater than the TMDL require reductions, so percent reductions in TN loads are the same as percent reductions in TN concentrations. For Threemile Creek, there were two TN target exceedances from two different sampling events at the Ambrose Confluence sampling location, so TN reductions were calculated and plotted for both exceedances at that site. Based on the results presented in **Figure 5-8**, TN load reductions ranging from 41% to 75%, with a median overall reduction of 60%, are necessary to meet the TMDL.

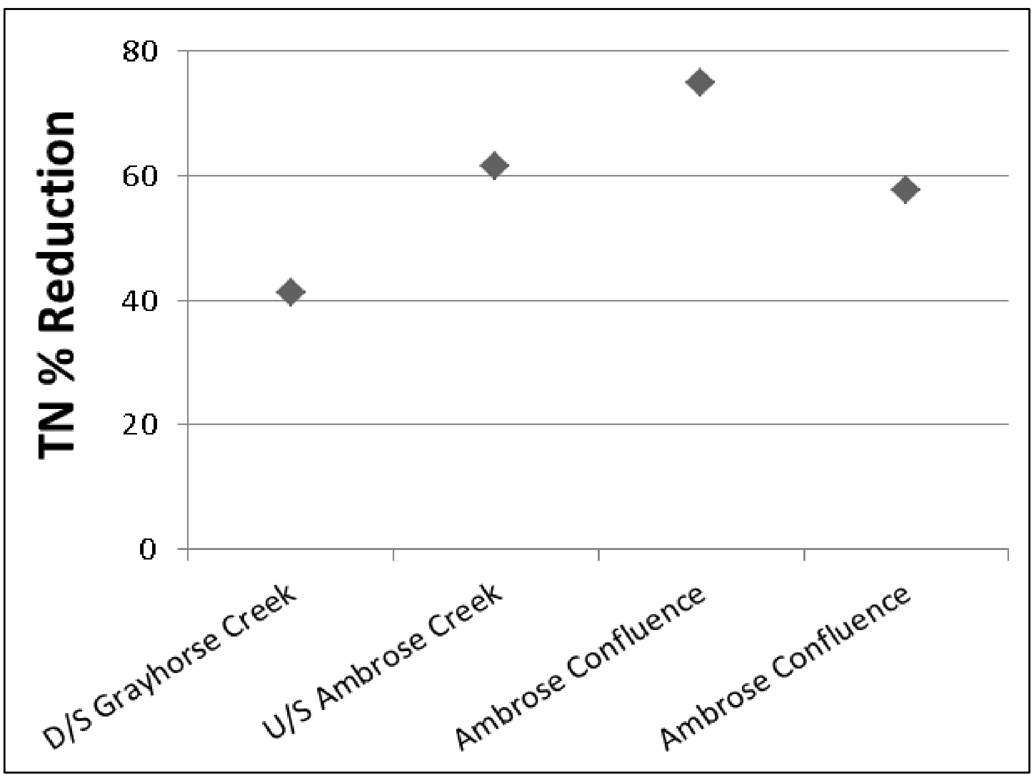


Figure 5-8. Measured TN Percent Load Reductions for Threemile Creek (Each TN target exceedance for a site were plotted.)

5.6.1.5 TP TMDL, Allocations, and Current Loading

The TMDL for TP is based on **Equation 5** and the TMDL allocations are based on **Equation 6.** The value of the TP TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. The following example TP TMDL for Threemile Creek uses **Equation 5** with the median measured flow from all sites during 2003-2010 sampling (7.02 cfs):

$$\textbf{TMDL = (0.030 mg/L) (7.02 cfs) (5.4) = 1.14 lbs/day}$$

Equation 7 is the basis for the natural background load allocation for TP. To continue with the example at a flow of 7.02 cfs, this allocation is as follows:

$$LA_{NB} = (0.010\ mg/L)\ (7.02\ cfs)\ (5.4) = 0.379\ lbs/day$$

Using **Equation 8**, the human-caused TP load allocation at 7.02 cfs can be calculated:

$$LA_{H} = 1.14\ lbs/day - 0.379\ lbs/day = 0.761\ lbs/day$$

An example total existing load is based on **Equation 9**, and is calculated as follows using the median of TP target exceedance values measured from Threemile Creek from 2003-2010 (0.104 mg/L) and the median measured flow of 7.02 cfs:

Total Existing Load = (0.104 mg/L) (7.02 cfs) (5.4) = 3.94 lbs/day

The portion of the total existing load attributed to human sources is 3.56 lbs/day, which is determined by subtracting out the 0.379 lbs/day background load. This 3.56 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-29 contains the results for the example TP TMDL, LAs, and current loading. In addition, it contains an example percent reduction to the human-caused LA required to meet the water quality target for TP. At the median growing season flow of 7.02 cfs, and the median of measured TP target exceedance values, the current loading in Threemile Creek is greater than the TMDL. Under these example conditions, a 79% reduction of human-caused TP loads, which results in an overall 71% reduction of TP in Threemile Creek, would result in the TMDL being met. The source assessment of the Threemile Creek watershed indicates that agriculture is the most likely sources of TP in Threemile Creek; load reductions should focus on limiting and controlling TP loading from this source. Meeting LAs for Threemile Creek may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 9.4.1**.

Table 5-29. Threemile Creek TP Example TMDL, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction
Natural Background	0.379	0.379	0%
Human-caused (primarily agriculture)	0.761	3.56	79%
	TMDL = 1.14	**Total = 3.94**	**Total = 71%**

[1]Based on a median growing season flow of 7.02 cfs

Figure 5-9 shows the percent reductions for TP loads measured in Threemile Creek from 2003-2010. Because flow data were absent for some of the water quality samples, reductions were calculated for any sample where the measured TP concentrations were above the target. Any time concentration exceeds the target, the corresponding load, even if flow is not measured, exceeds the TMDL since the TMDL equation is based on concentration multiplied by the flow. Loads greater than the TMDL require reductions, so percent reductions in TP loads are the same as percent reductions in TP concentrations. For Threemile Creek, there were multiple TP target exceedances at the Below Fish, Wildlife, and Parks (FWP) and Ambrose Confluence sampling locations, so the TP reductions for all exceedances at those sites were calculated and plotted. Based on the results presented in **Figure 5-9**, TP load reductions ranging from 27% to 79%, with a median overall reduction of 71%, are necessary to meet the TMDL.

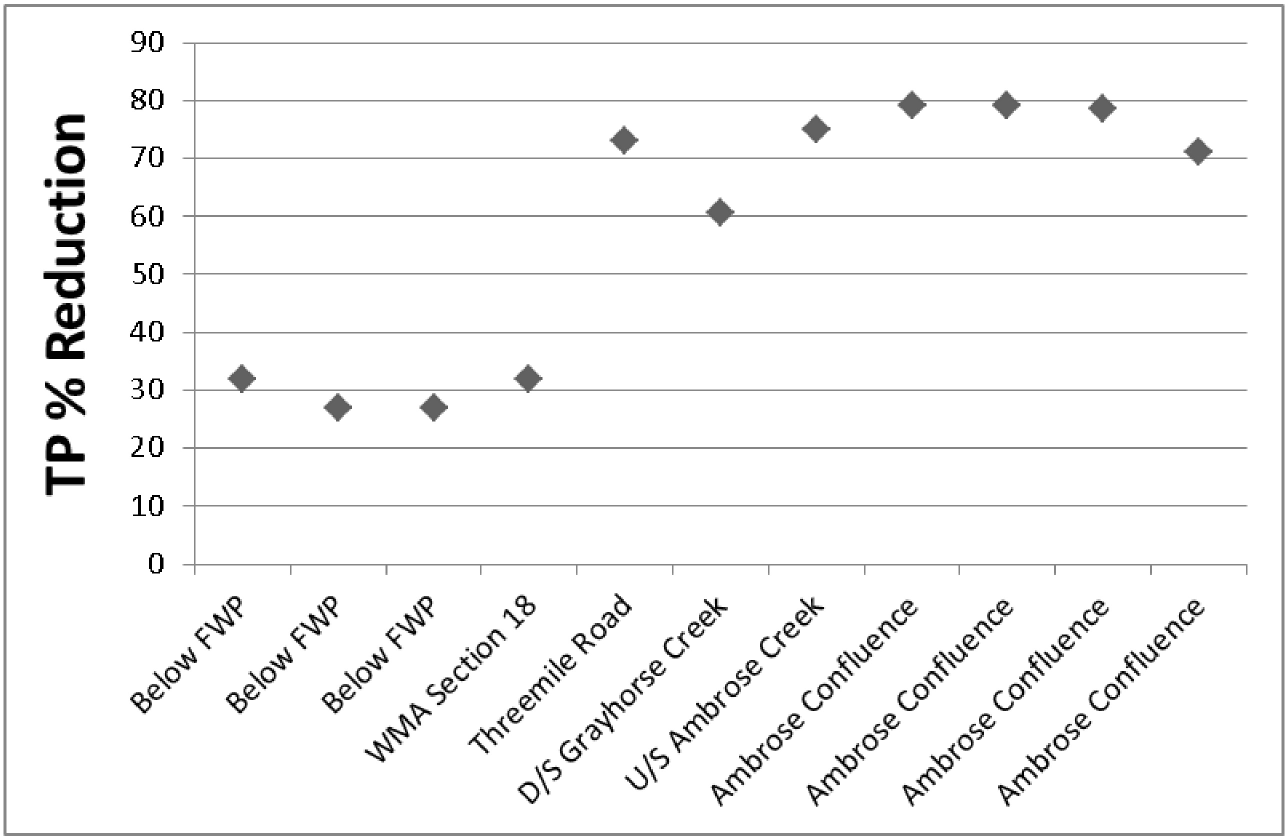


Figure 5-9. Measured TP Percent Load Reductions for Threemile Creek (Each TP target exceedance for a site were plotted.)

5.6.2 Ambrose Creek

Ambrose Creek flows from its headwaters in the Sapphire Mountains on the east side of the Bitterroot Valley to its confluence with Threemile Creek. The headwaters are predominately Bitterroot National Forest lands, while most of the 11.7 miles of creek flow through privately-owned lands. Ambrose Creek is the largest tributary to Threemile Creek, which is also currently listed as impaired by nutrients.

5.6.2.1 Assessment of Water Quality Results

The source assessment for Ambrose Creek consists of an evaluation of nutrient data, in particular, TN and TP concentrations, followed by an estimation of the most significant human-caused sources of nutrients. Although there were many TN and TP exceedances in Ambrose Creek, chlorophyll-*a* and AFDM concentrations were below targets. During field data collection, it was observed that there was excess fine sediment in the substrate and that the substrate was likely too fine for algal growth. **Figure**

5-10 presents the approximate locations of data pertinent to the source assessment in the Ambrose Creek watershed.

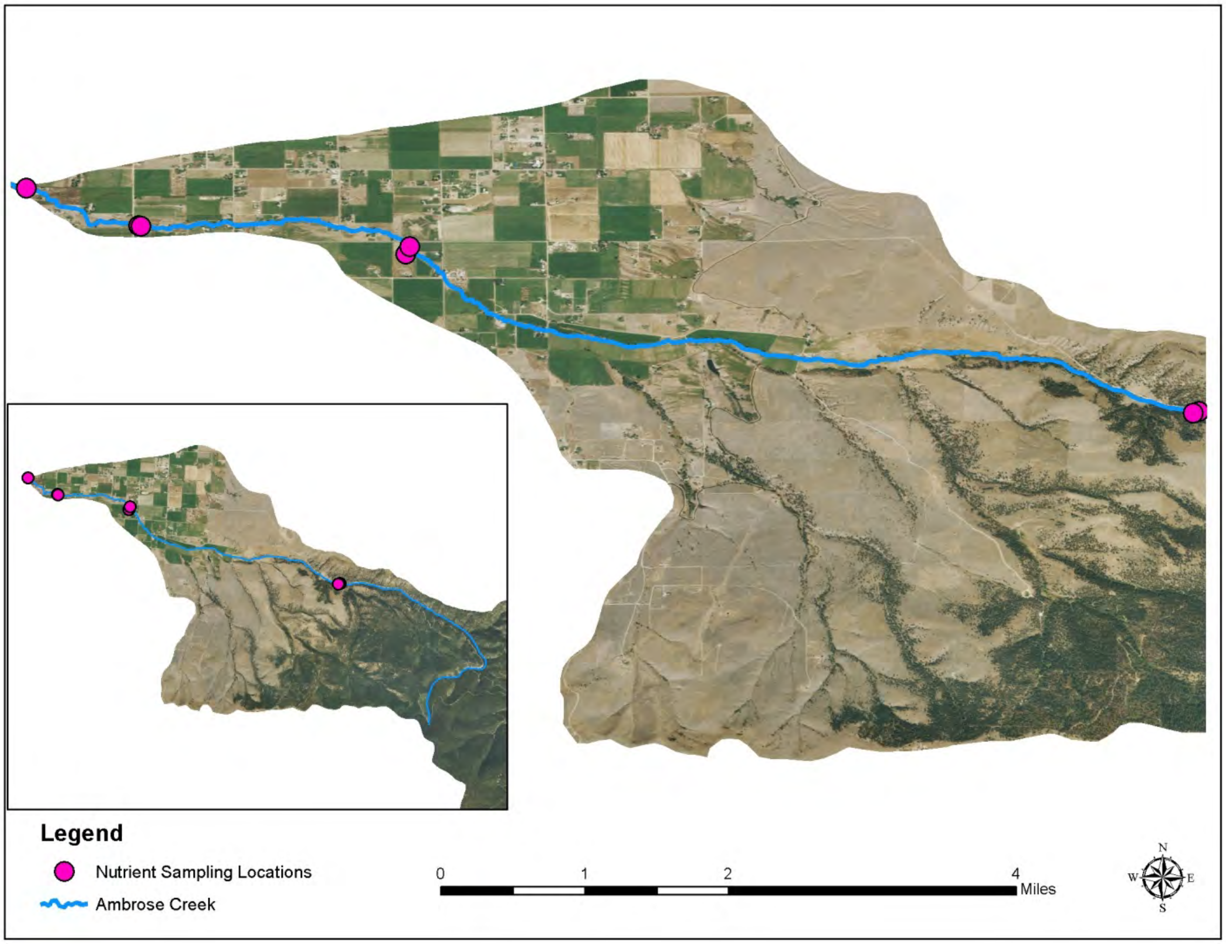


Figure 5-10. Ambrose Creek Watershed with Water Quality Sampling Locations

Total Nitrogen

DEQ and TSWQC collected water quality samples for TN from Ambrose Creek during the growing season between 2003 and 2012 (**Section 5.4.3.1, Table 5-3**). With the exception of upstream data collected near the USFS boundary, all downstream TN data starting at the Ambrose Creek Road Crossing exceeded the target of 0.300 mg/L. In general, the data show that the TN values increase in the downstream direction to the mouth, with concentrations highest near the mouth. A single sample collected near the mouth in 2012 was approximately 16 times greater than the water quality target. **Figure 5-11** presents summary statistics for TN concentrations at sampling sites in Ambrose Creek.

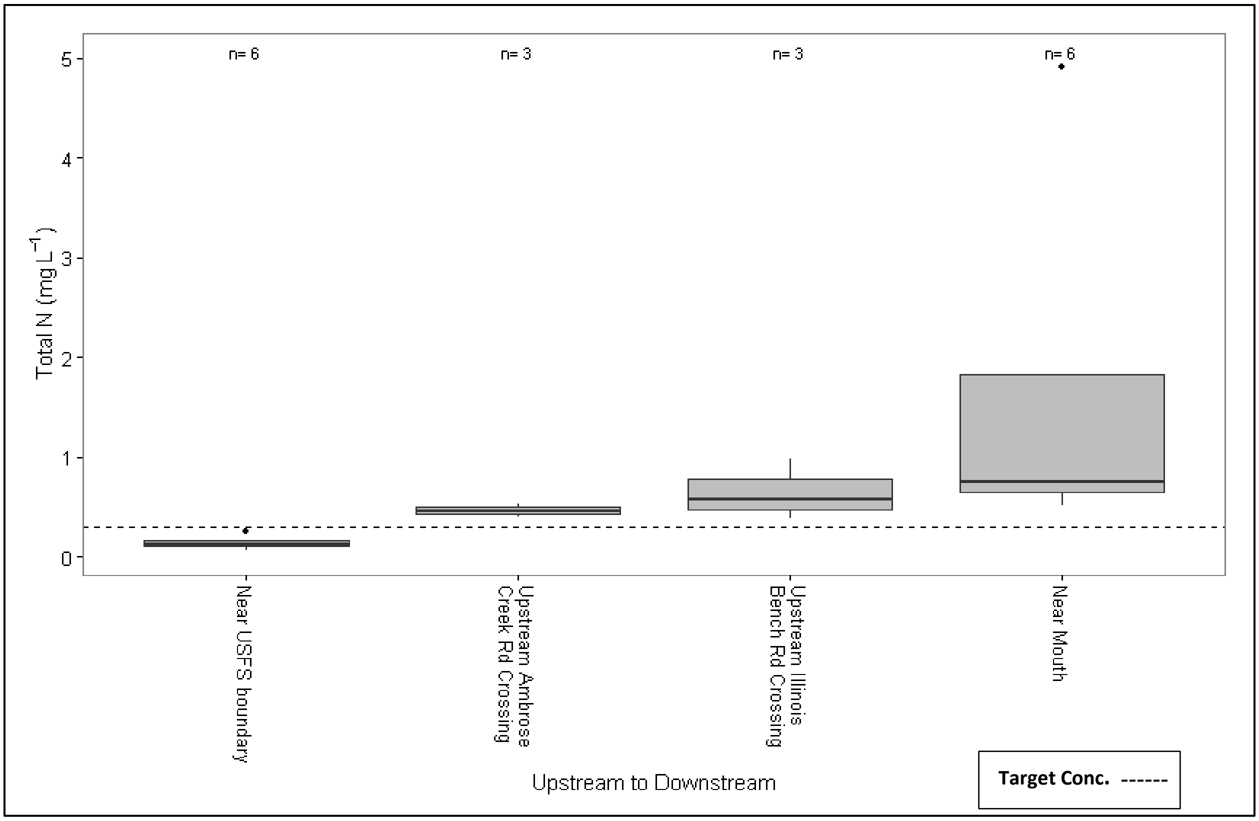


Figure 5-11. Boxplots of TN Concentrations in Ambrose Creek (2003-2012)

Total Phosphorus

DEQ and TSWQC collected water quality samples for TP from Ambrose Creek during the growing season between 2007 and 2012 (**Section 5.4.3.1, Table 5-3**). All TP data exceeded the target of 0.030 mg/L. In general, there is a significant increase in TP concentrations from the samples collected near the USFS boundary to the samples collected further downstream in the valley agricultural and residential areas; the median concentration of TP for the samples collected near the USFS boundary is 0.061 mg/L, while the median concentration of the next downstream sampling location Upstream Ambrose Creek Rd Crossing is 0.195 mg/L. There is significant agricultural influence between these two monitoring locations. **Figure 5-12** presents summary statistics of TP concentrations at sampling sites in Ambrose Creek.

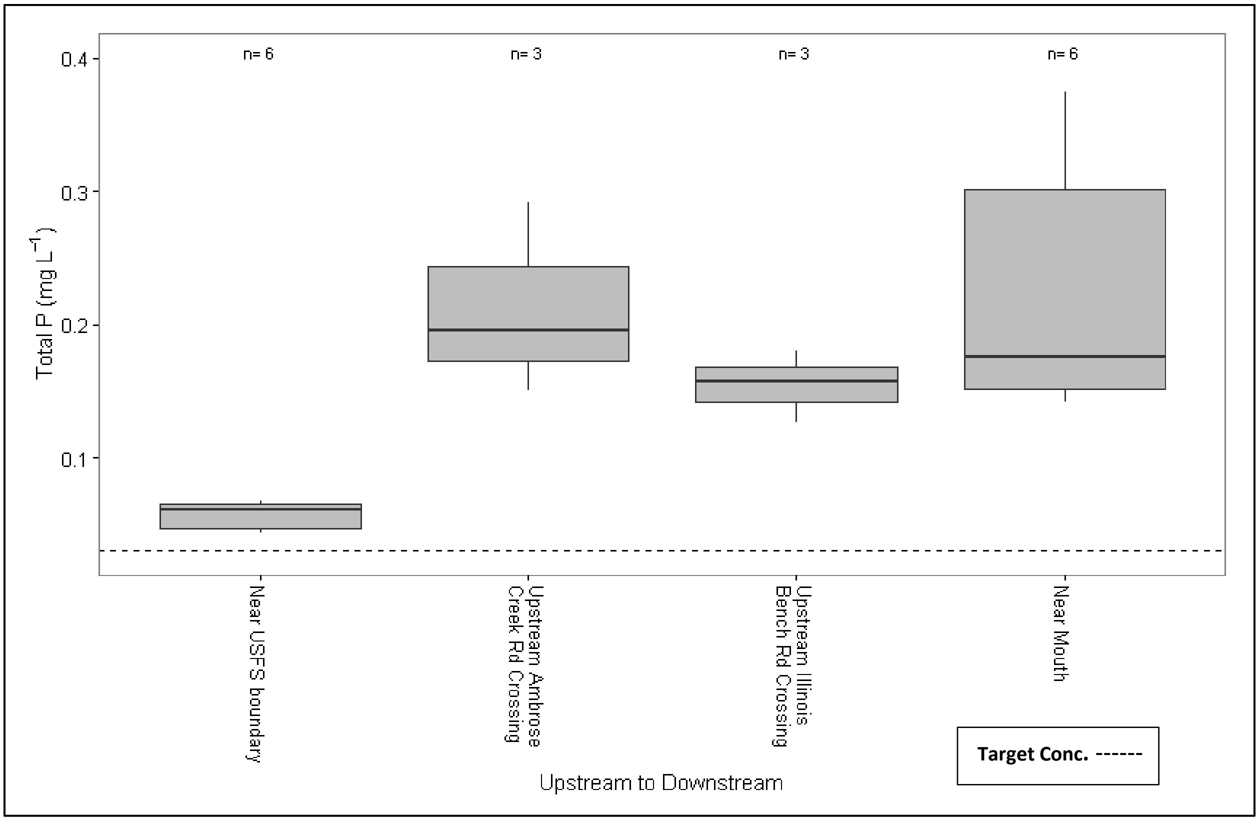


Figure 5-12. Boxplots of TP Concentrations in Ambrose Creek (2003-2012)

5.6.2.2 Source Assessment

The Ambrose Creek watershed includes forests, open grasslands and shrublands, pastures, and agricultural lands. The watershed contains private and public forest land, although a majority of the land cover in the lower reaches of the watershed is privately-owned agricultural (hay and pasture) and developed residential land. In addition, the valley is seeing increasing number of small acreage farms.

Excess nutrients in Ambrose Creek have been noted as a problem for several decades. In 1997-1998, Ravalli County performed a study of nonpoint nutrient issues in the Bitterroot River watershed, which included Threemile Creek (Hooten, 1999). In 2002 and 2003, the Tri-State Water Quality Council (TSWQC) conducted an extensive watershed assessment of Ambrose Creek as part of a larger watershed assessment of the Ambrose-Threemile Creek watershed (McDowell and Rokosch, 2005). The data from both studies demonstrated that nutrient concentrations in Ambrose and Threemile Creeks tended to be high in comparison to other streams in the Bitterroot River watershed.

In May 1991, DEQ conducted a Nonpoint Source Stream Reach Assessment on the lower three-quarters of Ambrose Creek, which indicated notable sediment production from riparian grazing, livestock bank trampling, silvicultural activities, and roads. Intensive, poorly managed grazing activities were identified as major sources of habitat alteration and sediment delivery in the lower reach (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011a). Historic assessment records indicate that the severe impairment was due to improper grazing practices, dewatering, and damaged riparian.

A sediment TMDL for Ambrose Creek was completed in 2011 (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011a). As part of sediment TMDL development, DEQ performed an assessment of riparian condition and near-stream land uses in 2007 and found that of 50% of the streambank along Ambrose Creek had significant human-caused effects within 100 feet of the channel. These human-caused effects appeared to be having a negative impact on riparian health. Of the more than 18 miles of its banks (accounting for both banks) rated as poor or fair condition, 17.6 miles (98%) were in areas where anthropogenic effects were observed. In contrast, all but a trace amount of the riparian areas in which no anthropogenic effects were observed were identified as being in good condition (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011a). During DEQ monitoring in 2012, it was observed that Ambrose Creek had an incised channel going through an agricultural area and the riparian vegetation was either cleared or had been severely grazed. The land use activities that are increasing sediment supplies to Ambrose Creek are also likely linked to increased nutrient supplies.

Potential human sources that could contribute TP and TN to Ambrose Creek are agriculture (crops, grazing in riparian or streamside zones, livestock confinement areas), urban development, septic, silvicultural activities, and historic mining; the primary land use and most likely significant nutrient source in Ambrose Creek is agriculture (irrigated crops, grazing in riparian or streamside zones, livestock confinement areas). Each of the potential human sources is discussed below, followed by an analysis of the sources.

Agriculture

The primary land use and the most likely significant nutrient source in the Ambrose Creek watershed is agriculture, which includes irrigated cropland and grazing/pasture in the valley portion of the watershed. Essentially all crops in the watershed are irrigated. Irrigated cropland includes primarily alfalfa and hay, with small acreages of sod/grass seed and small grains (i.e., spring wheat, barley).

The Bitterroot Irrigation District (BRID) canal is a primary source of irrigation water on the eastern side of the Bitterroot valley. The drainage area upgradient of the BRID system is primarily rangeland so agricultural input from irrigated crops would be downgradient from the system. Based on conversations with the irrigation managers for the BRID and analysis of the canal and Ambrose Creek channel intersections, the inter-basin nutrient loads transferred to the systems are insignificant. However, including livestock influence, this trans-basin diversion may contribute flow and a nutrient load to the irrigated portion of Ambrose Creek through groundwater supplements or overland flow from flood irrigation.

There are several large and small acreage ranches and farms along the creek. It was noted during 2012 and 2013 field observations, that there is significant livestock grazing in the stream channel and along the riparian corridor of most of the reach as it enters the agricultural areas. There is cattle access to the stream and small confined pens of cattle, horses, and other livestock were observed within close proximity to the stream or where the stream flows through the penned area. The stream channel was severely impacted from grazing activities and there was almost no remaining riparian vegetation along significant sections in the agricultural areas of lower Ambrose Creek.

The Ambrose grazing allotment comprises 1,677 acres of USFS administered lands contained in the Ambrose Creek watershed with an average number of 26 permitted AUMs on the allotment (**Table 5-24**) in any given year. Located in the forested areas of the upper watershed, the allotment is not grazed in all years and in the past 10 years was not grazed in 2007, 2009, and 2011-2012. Based on water quality data, the grazing allotments do not appear to be a significant source of nutrients.

Silviculture

Approximately 42% of the Threemile Creek watershed, which includes Ambrose Creek, is forested. The forested upper watershed seems to contribute little to the excess nutrient load to Threemile and Ambrose Creeks (McDowell and Rokosch, 2005). Nitrogen in the forested reaches is generally below natural background. Although phosphorus in the forested reaches is approximately six times greater than natural background, the upper reaches are only a minor contribution of the TP load.

An analysis of aerial imagery and geospatial land cover data shows parcels of land, both private and public, with recently harvested forest in the upper Ambrose Creek watershed. There have been several forest management activities in the south-eastern portion of the Ambrose Creek watershed in the past 10 years according to GIS information provided by the Bitterroot National Forest, although these operations are not within close proximity to the stream channel. Timber harvest has occurred on parcels on both sides of the stream channel and aerial imagery show a network of unpaved forest roads in the watershed that may contribute sediment loads to the stream. Based on the data presented in **Figures 5-11** and **5-12**, contributions of nutrients to Ambrose Creek from silviculture are likely insignificant.

Subsurface Wastewater Treatment and Disposal

According to DEQ, there are numerous individual septic systems in the Ambrose Creek watershed. All of the individual septic systems are concentrated in the valley area, in the downstream part of the watershed, and in some places the septic density is over 100 septic units per square mile. There are a number of systems within close proximity (<100 ft) to the stream. These systems are likely part of the total nutrient loads into the creek and are likely a more important contributor of nitrogen than phosphorus.

Mining

According to DEQ and MBMG databases, there is one abandoned mine listed in the Ambrose Creek watershed, which is listed as a titanium, iron, and thorium mine. This abandoned placer mine is located near the USFS boundary. TN and NO_3 + NO_2 concentrations are well below targets at sampling locations near the USFS boundary, so it is not clear if the historic mining activity in Ambrose Creek is contributing nutrients to the watershed.

5.6.2.3 TN TMDL, Allocations, and Current Loading

The TMDL for TN is based on **Equation 5** and the TMDL allocations are based on **Equation 6.** The value of the TN TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. The following example TN TMDL for Ambrose Creek uses **Equation 5** with the median measured flow from all sites during 2007-2012 sampling (0.45 cfs):

TMDL = (0.300 mg/L) (0.45 cfs) (5.4) = 0.729 lbs/day

Equation 7 is the basis for the natural background load allocation for TN. To continue with the example at a flow of 0.45 cfs, this allocation is as follows:

LA_{NB} = (0.095 mg/L) (0.45 cfs) (5.4) = 0.231 lbs/day

Using **Equation 8**, the human-caused TN load allocation at 0.45 cfs can be calculated:

$$LA_H = 0.729 \text{ lbs/day} – 0.231 \text{ lbs/day} = 0.498 \text{ lbs/day}$$

An example total existing load is based on **Equation 9**, and is calculated as follows using the median of TN target exceedance values measured from Ambrose Creek from 2007-2012 (0.57 mg/L) and the median measured flow of 0.45 cfs:

Total Existing Load = (0.57 mg/L) (0.45 cfs) (5.4) = 1.39 lbs/day

The portion of the total existing load attributed to human sources is 1.15 lbs/day, which is determined by subtracting out the 0.231 lbs/day background load. This 1.15 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-30 contains the results for the example TN TMDL, LAs, and current loading. In addition, it contains an example percent reduction to the human-caused LA required to meet the water quality target for TN. At the median growing season flow of 0.45 cfs, and the median of measured TN target exceedance values, the current loading in Ambrose Creek is greater than the TMDL. Under these example conditions, a 57% reduction of human-caused TN loads, which results in an overall 47% reduction of TN in Ambrose Creek, would result in the TMDL being met. The source assessment of the Ambrose Creek watershed indicates that agriculture is the most likely predominant source of TN in Ambrose Creek; load reductions should focus on limiting and controlling TN loading from these sources. Meeting LAs for Ambrose Creek may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 9.4.1**.

Table 5-30. Ambrose Creek TN Example TMDL, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction
Natural Background	0.231	0.231	0%
Human-caused (primarily agriculture)	0.498	1.15	57%
	TMDL = 0.729	**Total = 1.39**	**Total = 47%**

[1]Based on a median growing season flow of 0.45 cfs

Figure 5-13 shows the percent reductions for TN loads measured in Ambrose Creek from 2003-2012. Because flow data were absent for some of the water quality samples, reductions were calculated for the sampling locations where the measured TN concentrations were above the target. Any time concentration exceeds the target, the corresponding load, even if flow is not measured, exceeds the TMDL since the TMDL equation is based on concentration multiplied by the flow. Loads greater than the TMDL require reductions, so percent reductions in TN loads are the same as percent reductions in TN concentrations. For Ambrose Creek, there were multiple TN target exceedances from different sampling events at three of the sampling locations, so the TN reductions for all exceedances at those sites were calculated and plotted. Based on the results presented in **Figure 5-13**, TN load reductions ranging from 21% to 94%, with a median overall reduction of 47%, are necessary to meet the TMDL.

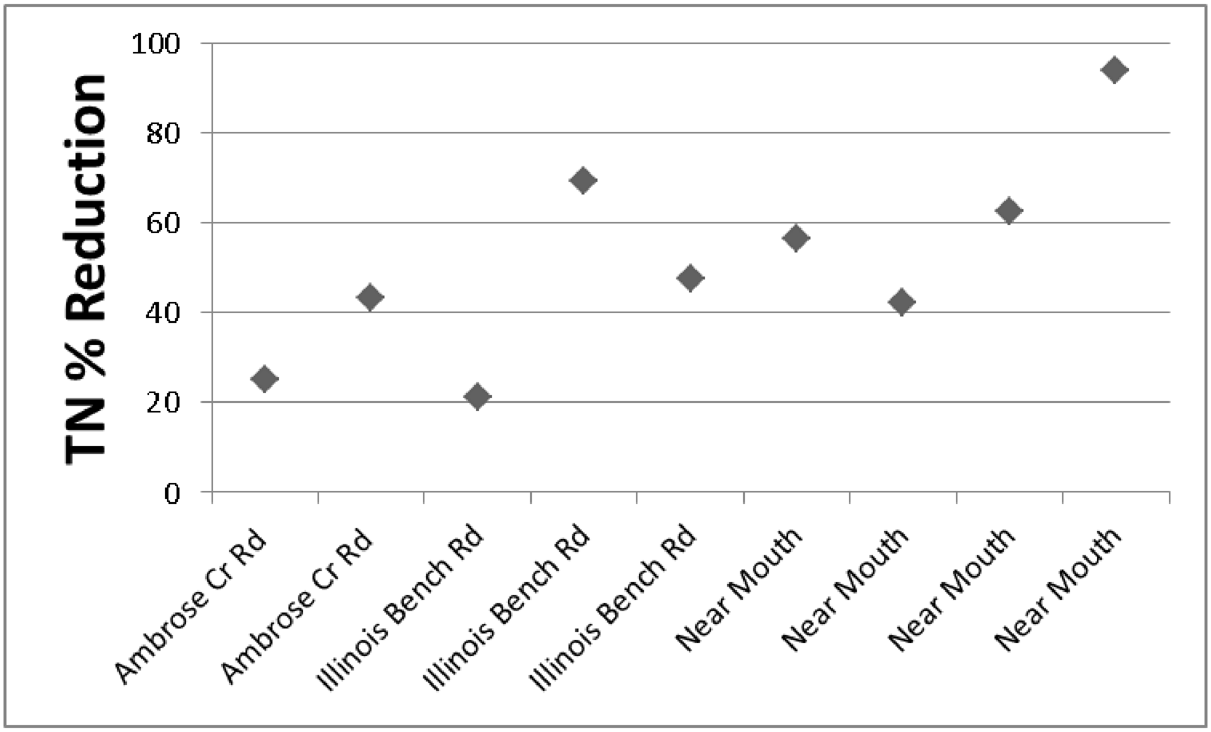


Figure 5-13. Measured TN Percent Load Reductions for Ambrose Creek (Each TN target exceedance for a site were plotted.)

5.6.2.4 TP TMDL, Allocations, and Current Loading

The TMDL for TP is based on **Equation 5** and the TMDL allocations are based on **Equation 6.** The value of the TP TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. The following example TP TMDL for Ambrose Creek uses **Equation 5** with the median measured flow from all sites during 2003-2012 sampling (0.45 cfs):

TMDL = (0.030 mg/L) (0.45 cfs) (5.4) = 0.073 lbs/day

Equation 7 is the basis for the natural background load allocation for TP. To continue with the example at a flow of 0.45 cfs, this allocation is as follows:

$$LA_{NB} = (0.010 \text{ mg/L}) (0.45 \text{ cfs}) (5.4) = 0.024 \text{ lbs/day}$$

Using **Equation 8**, the human-caused TP load allocation at 0.45 cfs can be calculated:

$$LA_{H} = 0.073 \text{ lbs/day} – 0.024 \text{ lbs/day} = 0.049 \text{ lbs/day}$$

An example total existing load is based on **Equation 9**, and is calculated as follows using the median of TP target exceedance values measured from Ambrose Creek from 2003-2012 (0.15 mg/L) and the median measured flow of 0.45 cfs:

Total Existing Load = (0.15 mg/L) (0.45 cfs) (5.4) = 0.364 lbs/day

The portion of the total existing load attributed to human sources is 0.340 lbs/day, which is determined by subtracting out the 0.024 lbs/day background load. This 0.340 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-31 contains the results for the example TP TMDL, LAs, and current loading. In addition, it contains an example percent reduction to the human-caused LA required to meet the water quality target for TP. At the median growing season flow of 0.45 cfs, and the median of measured TP target exceedance values, the current loading in Ambrose Creek is greater than the TMDL. Under these example conditions, an 86% reduction of human-caused TP loads, which results in an overall 80% reduction of TP in Ambrose Creek, would result in the TMDL being met. The source assessment of the Ambrose Creek watershed indicates that agriculture is the most likely predominant source of TP in Ambrose Creek; load reductions should focus on limiting and controlling TP loading from these sources. Meeting LAs for Ambrose Creek may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 9.4.1**.

Table 5-31. Ambrose Creek TP Example TMDL, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction
Natural Background	0.024	0.024	0%
Human-caused (primarily agriculture)	0.049	0.340	86%
	TMDL = 0.073	**Total = 0.364**	**Total = 80%**

[1]Based on a median growing season flow of 0.45 cfs

Figure 5-14 shows the percent reductions for TP loads measured in Ambrose Creek from 2003-2012. Because flow data were absent for some of the water quality samples, percent reductions were calculated for the sampling locations where the measured TP concentrations were above the target. Any time concentration exceeds the target, the corresponding load, even if flow is not measured, exceeds the TMDL since the TMDL equation is based on concentration multiplied by the flow. Loads greater than the TMDL require reductions, so percent reductions in TP loads are the same as percent reductions in TP concentrations. For Ambrose Creek, there were multiple TP target exceedances for different sampling events at all four sampling locations, so the TP reductions for all exceedances at those sites were calculated and plotted. Based on the results presented in **Figure 5-14**, TP load reductions ranging from 30% to 92%, with a median overall reduction of 80%, are necessary to meet the TMDL.

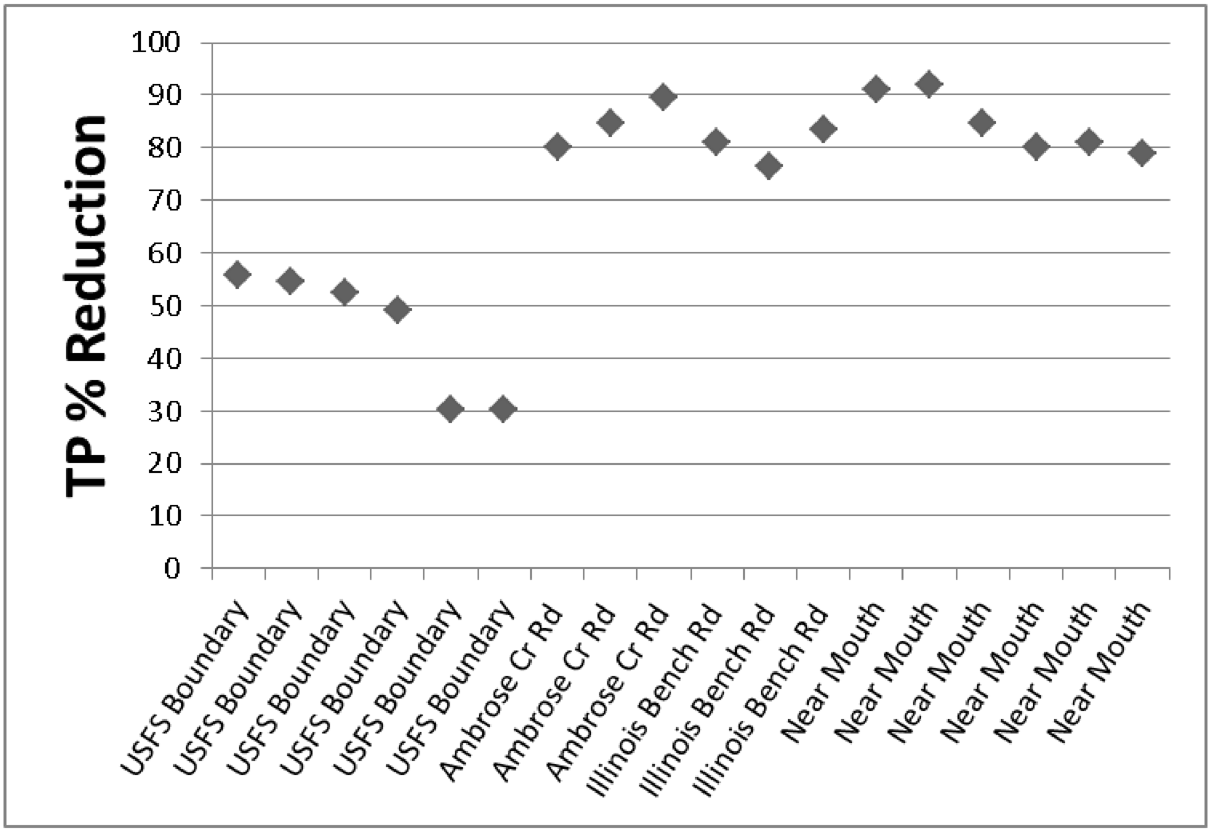


Figure 5-14. Measured TP Percent Load Reductions for Ambrose Creek (Each TP target exceedance for a site were plotted.)

5.6.3 Bass Creek

Bass Creek originates at Bass Lake in the Bitterroot Mountains on the west side of the Bitterroot Valley, and flows approximately 10 miles to its confluence with the Bitterroot River. The assessment unit includes 5.1 miles of the stream from the Selway-Bitterroot Wilderness boundary to the mouth (un-named channel of the Bitterroot River). The lower two miles flow through mostly private agricultural lands.

5.6.3.1 Assessment of Water Quality Results

The source assessment for Bass Creek consists of an evaluation of nutrient data, in particular, TN and TP concentrations, followed by an estimation of the most significant human-caused sources of nutrients. **Figure 5-15** presents the approximate locations of data pertinent to the source assessment in the Bass Creek watershed.

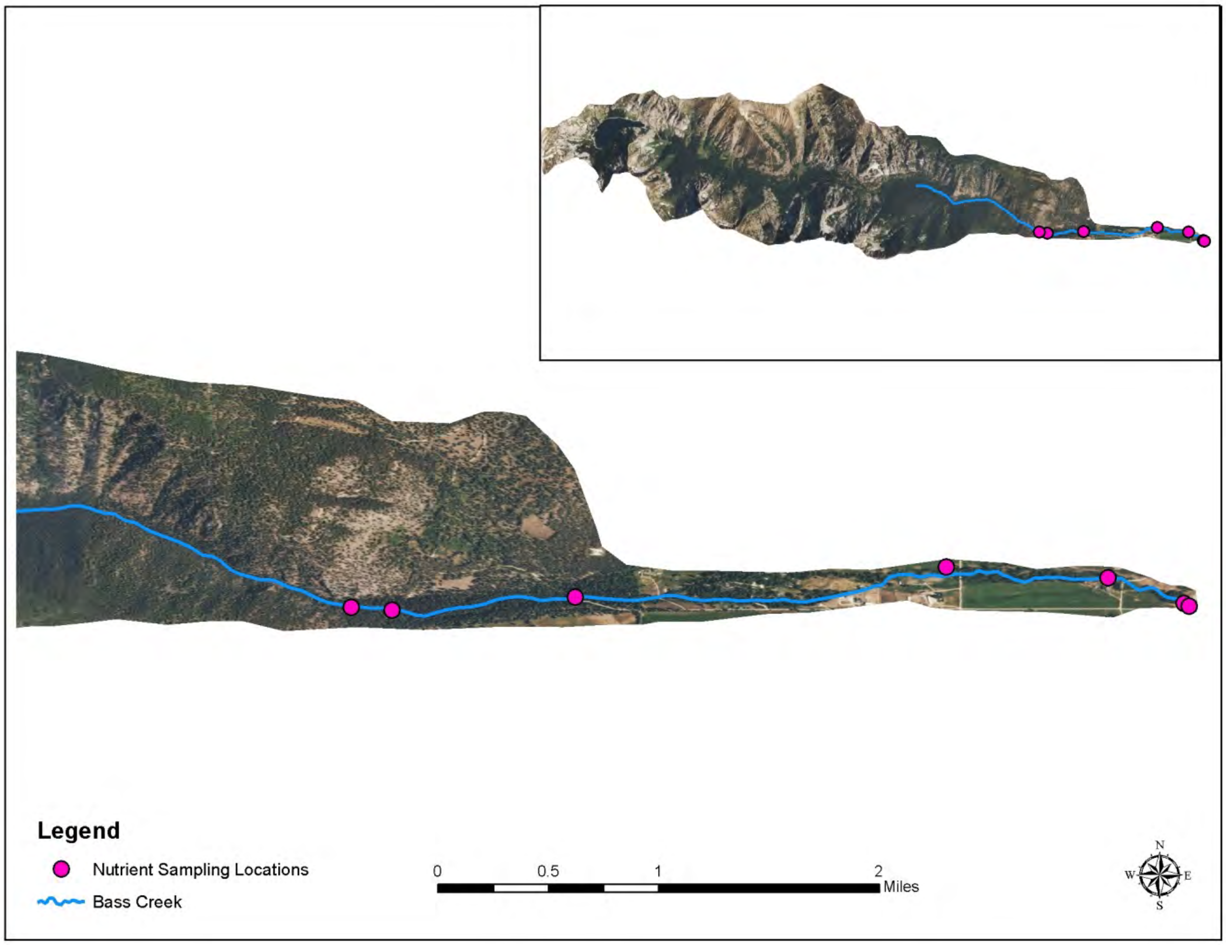


Figure 5-15. Bass Creek Watershed with Water Quality Sampling Locations

Total Nitrogen
DEQ collected water quality samples for TN from Bass Creek during the growing season between 2007 and 2012 (**Section 5.4.3.2, Table 5-5**). Out of 12 total samples, 3 exceeded the TN target of 0.275 mg/L. All of the exceedances for Bass Creek occurred at the Highway 93 crossing near the mouth. **Figure 5-16** presents summary statistics for TN concentrations at sampling sites in Bass Creek.

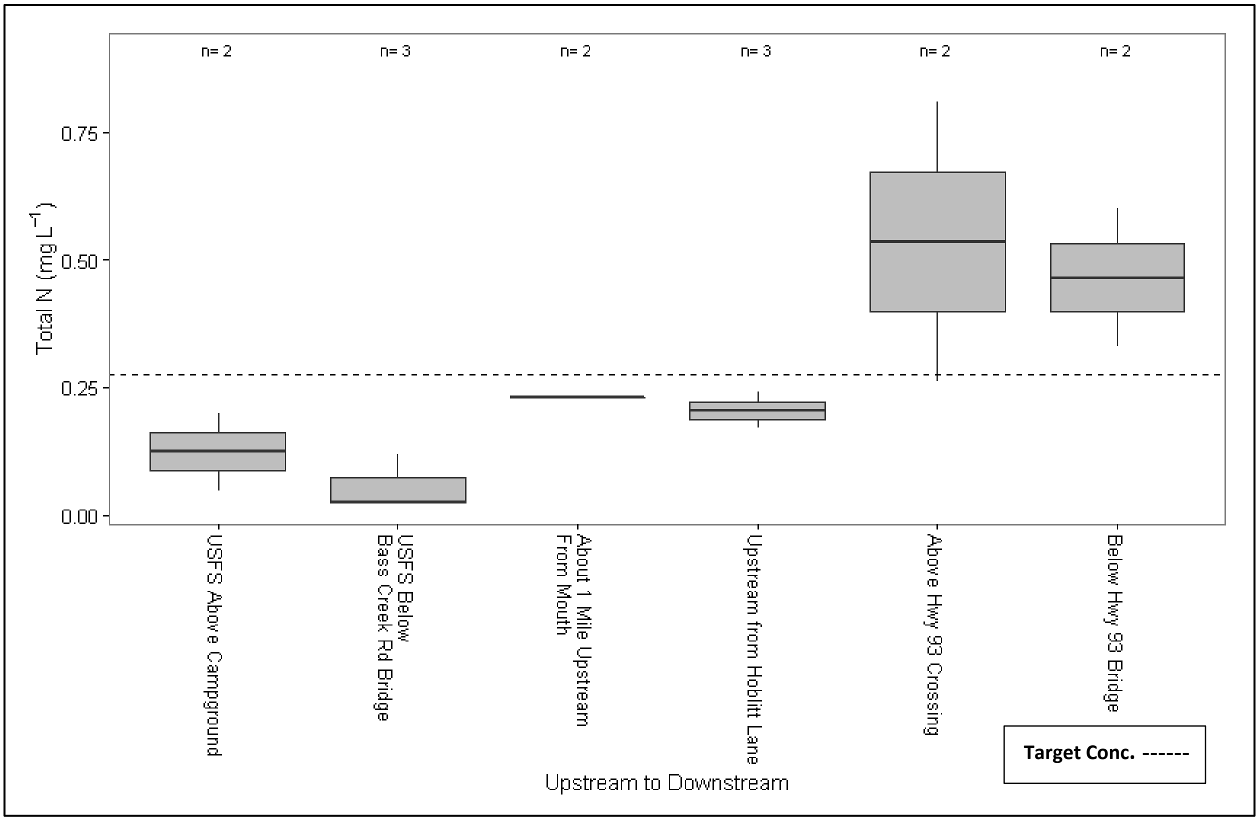


Figure 5-16. Boxplots of TN Concentrations in Bass Creek (2007-2012)

Total Phosphorus

DEQ collected water quality samples for TP from Bass Creek during the growing season between 2004 and 2012 (**Section 5.4.3.2, Table 5-5**). Out of 15 total samples, 6 exceeded the TP target of 0.025 mg/L. The data collected on USFS land do not have any exceedances; the first exceedance occurs at the monitoring location about one mile upstream from the mouth and the other exceedances occur between that monitoring location and the mouth. **Figure 5-17** presents summary statistics for TN concentrations at sampling sites in Bass Creek.

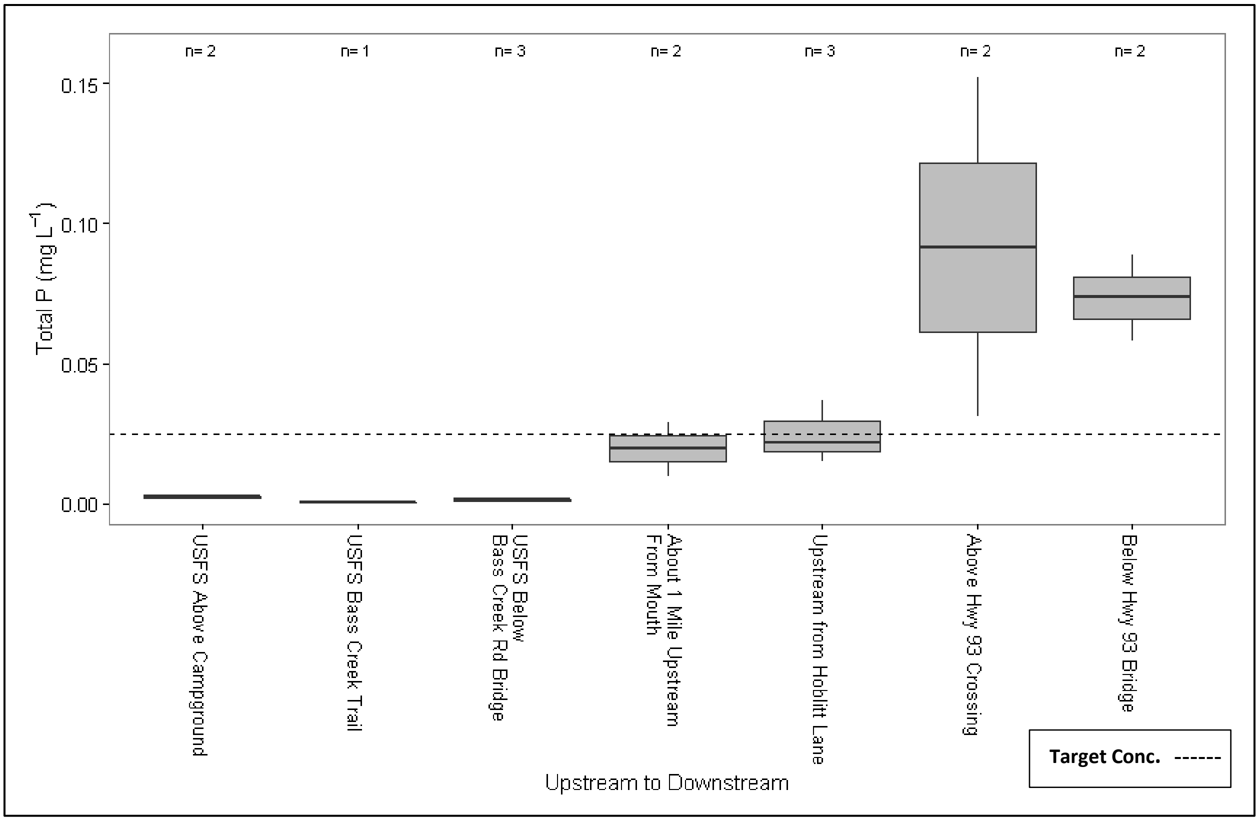


Figure 5-17. Boxplots of TP Concentrations in Bass Creek (2004-2012)

5.6.3.2 Source Assessment

The majority of the Bass Creek watershed drains forest land cover in the Bitterroot National Forest. Although the majority of the watershed is forested, large properties with hay or pasture exist on privately-owned land downstream of the USFS boundary.

A sediment TMDL for Bass Creek was completed in 2011 (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011a). As part of sediment TMDL development, DEQ performed stream assessments in 2007 along Bass Creek and the data collected as part of the assessment by DEQ field crew in 2007 suggested that agriculture is having a potentially significant impact on stream health. During the stream assessments performed in 2007, field crews observed that a site located on private property a short distance from the confluence with the Bitterroot River appeared to be in a state of recovery and portions were still overwidened. Those portions of Bass Creek's riparian areas that were rated as good condition were dominated by forest land uses; while those as fair or poor conditions were dominated by agriculture and near-stream roads.

The last mile on Bass Creek, from Larry Creek Road to the mouth, is on the Montana Fish, Wildlife and Parks Dewatered Streams List as being chronically dewatered. The list refers to streams that are significantly reduced in streamflow to the point where fish are seriously impacted.

Potential human sources that could contribute TP and TN to Bass Creek are agriculture (irrigated crops, grazing/pasture), septic, silvicultural activities, and historic mining; the primary land use and most likely significant nutrient source in Bass Creek is agriculture. Each of the potential human sources is discussed below, followed by an analysis of the sources.

Agriculture
The primary land use and the most likely significant nutrient source in the Bass Creek watershed is agriculture, which includes irrigated cropland and grazing/pasture. Irrigated cropland includes primarily hay with some alfalfa, with minimal winter wheat. Recent field observations noted hummocking and cattle access to the stream with noticeable early spring algal growth on the lower reach of Bass Creek near the mouth. Large cattle operations border a significant portion of the stream reach and cattle were observed grazing in the spring and summer with access to some sections of the stream. Where there was access, trampled willows in the riparian corridor were observed. It appears that the lower impacted portions of the stream would recover well with riparian plantings and grazing management.

Located on USFS administered lands near the national forest boundary, the Bass grazing allotment comprises 315 acres with an average number of 100 permitted AUMs (**Table 5-24**) in any given year. The Bass Creek allotment is primarily in the Larry Creek watershed to the south, but 22 acres of the allotment overlaps the southern part of the Bass Creek watershed below Charles Waters Campground.

From geospatial database information, there are numerous small irrigation withdrawals from Bass Creek below the forest boundary. Within the watershed and including livestock sources, irrigation return flows from overland runoff and groundwater recharge in the lower drainage may be likely flow pathways by which nutrients are reaching Bass Creek.

Subsurface Wastewater Treatment and Disposal
According to DEQ information, there are 11 individual septic systems in the Bass Creek watershed area. Most of the systems are well away from the stream corridor with only one that is within close proximity (<100 ft) to the stream. While these certainly constitute a portion of the nutrient load to Bass Creek, they are likely having a negligible influence on instream nutrient concentrations.

Silviculture
The majority of the land cover in the Bass Creek watershed is forest. An analysis of aerial imagery and geospatial land cover data shows several parcels of recently harvested forest in the watershed. On the north side of the creek near the USFS boundary some forest management activities occurred on a large almost 300 acre area in the past years, in addition to a small, 11 acre parcel on the north side of the creek below the Larry Creek drainage. In addition to the harvest activities, aerial images of the watershed show an unpaved forestry road (Larry Creek Road), northwest of the Charles Waters Memorial Campground which is not in close proximity to the stream. Based on the data presented in **Figures 5-16** and **5-17**, contributions of nutrients to Bass Creek from silviculture are likely insignificant.

Mining
According to DEQ and MBMG databases, there are three abandoned mines listed in the Bass Creek watershed. Two lode mines, the Cliff Mine, which is a lead and zinc mine, and an unnamed lead and silver mine, are in the mountainous terrain of St. Joseph's and St. Mary's peaks in the upper watershed. The other mine, is a kyanite mine named Bass Creek Silimanite, and is located upstream of the endpoint of the Bass Creek assessment unit. As the NO_3+NO_2 and TN concentrations are well below targets in the most upstream sampling locations, the historic mining activities do not provide a clear linkage as a source of nutrients in Bass Creek.

5.6.3.3 TN TMDL, Allocations, and Current Loading

The TMDL for TN is based on **Equation 5** and the TMDL allocations are based on **Equation 6.** The value of the TN TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. The following example TN TMDL for Bass Creek uses **Equation 5** with the median measured flow from all sites during 2007-2012 sampling (0.93 cfs):

TMDL = (0.275 mg/L) (0.93 cfs) (5.4) = 1.38 lbs/day

Equation 7 is the basis for the natural background load allocation for TN. To continue with the example at a flow of 0.93 cfs, this allocation is as follows:

LA_{NB} = (0.070 mg/L) (0.93 cfs) (5.4) = 0.352 lbs/day

Using **Equation 8**, the human-caused TN load allocation at 0.93 cfs can be calculated:

LA_{H} = 1.38 lbs/day – 0.352 lbs/day = 1.03 lbs/day

An example total existing load is based on **Equation 9**, and is calculated as follows using the median of TN target exceedance values measured from Bass Creek from 2007-2012 (0.600 mg/L) and the median measured flow of 0.93 cfs:

Total Existing Load = (0.600 mg/L) (0.93 cfs) (5.4) = 3.01 lbs/day

The portion of the total existing load attributed to human sources is 2.66 lbs/day, which is determined by subtracting out the 0.352 lbs/day background load. This 2.66 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-32 contains the results for the example TN TMDL, LAs, and current loading. In addition, it contains an example percent reduction to the human-caused LA required to meet the water quality target for TN. At the median growing season flow of 0.93 cfs, and the median of measured TN target exceedance values, the current loading in Bass Creek is greater than the TMDL. Under these example conditions, a 61% reduction of human-caused TN loads, which results in an overall 54% reduction of TN in Bass Creek, would result in the TMDL being met. The source assessment of the Bass Creek watershed indicates that agriculture is the most likely predominant source of TN in Bass Creek; load reductions should focus on limiting and controlling TN loading from these sources. Meeting LAs for Bass Creek may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 9.4.1**.

Table 5-32. Bass Creek TN Example TMDL, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction
Natural Background	0.352	0.352	0%
Human-caused (agriculture)	1.03	2.66	61%
	TMDL = 1.38	**Total = 3.01**	**Total = 54%**

[1]Based on a median growing season flow of 0.93 cfs

Figure 5-18 shows the percent reductions for TN loads measured in Bass Creek from 2007-2012. Because flow data were absent for some of the water quality samples, percent reductions were calculated for the sampling locations where the measured TN concentrations were above the target. Any time concentration exceeds the target, the corresponding load, even if flow is not measured, exceeds the TMDL since the TMDL equation is based on concentration multiplied by the flow. Loads greater than the TMDL require reductions, so percent reductions in TN loads are the same as percent reductions in TN concentrations. For Bass Creek, there were two TN target exceedances from two different sampling events at the Below Hwy 93 Bridge sampling location, so both TN reductions were calculated and plotted for that site. Based on the results presented in **Figure 5-18**, TN load reductions ranging from 17% to 66%, with a median overall reduction of 54%, are necessary to meet the TMDL.

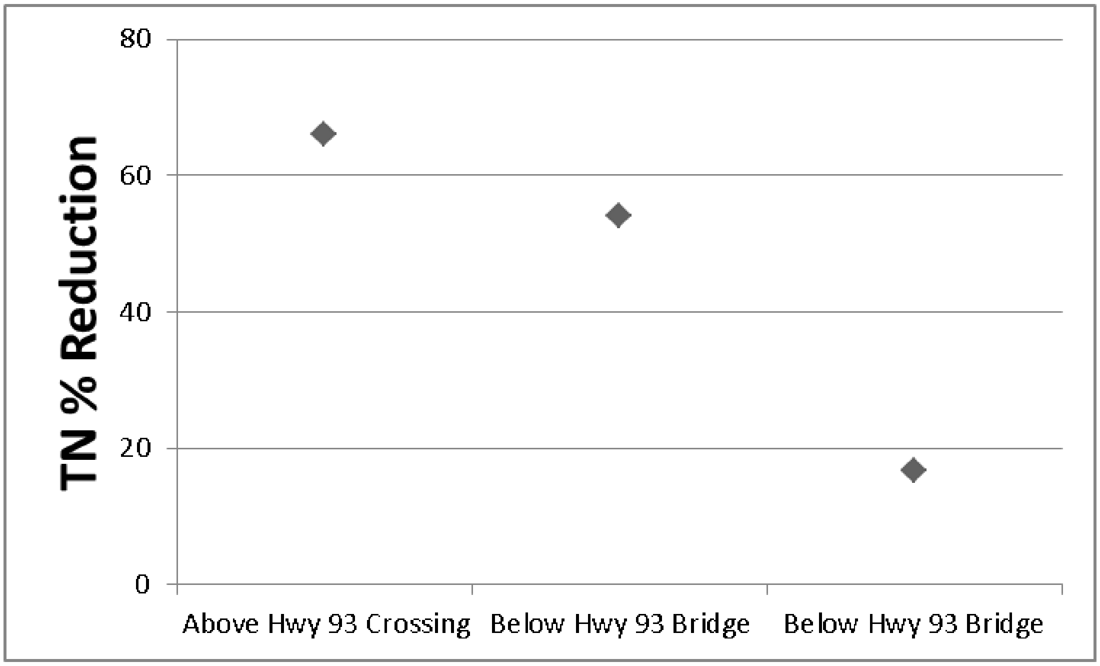


Figure 5-18. Measured TN Percent Load Reductions for Bass Creek (Each TN target exceedance for a site were plotted.)

5.6.3.4 TP TMDL, Allocations, and Current Loading

The TMDL for TP is based on **Equation 5** and the TMDL allocations are based on **Equation 6.** The value of the TP TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. The following example TP TMDL for Bass Creek uses **Equation 5** with the median measured flow from all sites during 2004-2012 sampling (0.93 cfs):

TMDL = (0.025 mg/L) (0.93 cfs) (5.4) = 0.126 lbs/day

Equation 7 is the basis for the natural background load allocation for TP. To continue with the example at a flow of 0.93 cfs, this allocation is as follows:

LA_{NB} = (0.006 mg/L) (0.93 cfs) (5.4) = 0.030 lbs/day

Using **Equation 8**, the human-caused TP load allocation at 0.93 cfs can be calculated:

LA_{H} = 0.126 lbs/day – 0.030 lbs/day = 0.095 lbs/day

An example total existing load is based on **Equation 9**, and is calculated as follows using the median of TP target exceedance values measured from Bass Creek from 2004-2012 (0.0475 mg/L) and the median measured flow of 0.93 cfs:

Total Existing Load = (0.0475 mg/L) (0.93 cfs) (5.4) = 0.239 lbs/day

The portion of the total existing load attributed to human sources is 0.208 lbs/day, which is determined by subtracting out the 0.030 lbs/day background load. This 0.208 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-33 contains the results for the example TP TMDL, LAs, and current loading. In addition, it contains an example percent reduction to the human-caused LA required to meet the water quality target for TP. At the median growing season flow of 0.93 cfs, and the median of measured TP target exceedance values, the current loading in Bass Creek is greater than the TMDL. Under these example conditions, a 54% reduction of human-caused TP loads, which results in an overall 47% reduction of TP in Bass Creek, would result in the TMDL being met. The source assessment of the Bass Creek watershed indicates that agriculture is the most likely predominant source of TP in Bass Creek; load reductions should focus on limiting and controlling TP loading from these sources. Meeting LAs for Bass Creek may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 9.4.1**.

Table 5-33. Bass Creek TP Example TMDL, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction
Natural Background	0.030	0.030	0%
Human-caused (agriculture)	0.095	0.208	54%
	TMDL = 0.126	**Total = 0.239**	**Total = 47%**

[1]Based on a median growing season flow of 0.93 cfs

Figure 5-19 shows the percent reductions for TP loads measured in Bass Creek from 2004-2012. Because flow data were absent for some of the water quality samples, percent reductions were calculated for the sampling locations where the measured TP concentrations were above the target. Any time concentration exceeds the target, the corresponding load, even if flow is not measured, exceeds the TMDL since the TMDL equation is based on concentration multiplied by the flow. Loads greater than the TMDL require reductions, so percent reductions in TP loads are the same as percent reductions in TP concentrations. For Bass Creek, there were two TP target exceedances from two different sampling events at the Above Hwy 93 Crossing and the Below Hwy 93 Bridge sampling locations, so TP reductions for each were calculated and plotted for each location. Based on the results presented in **Figure 5-19**, TP load reductions ranging from 14% to 84%, with a median overall reduction of 45%, are necessary to meet the TMDL.

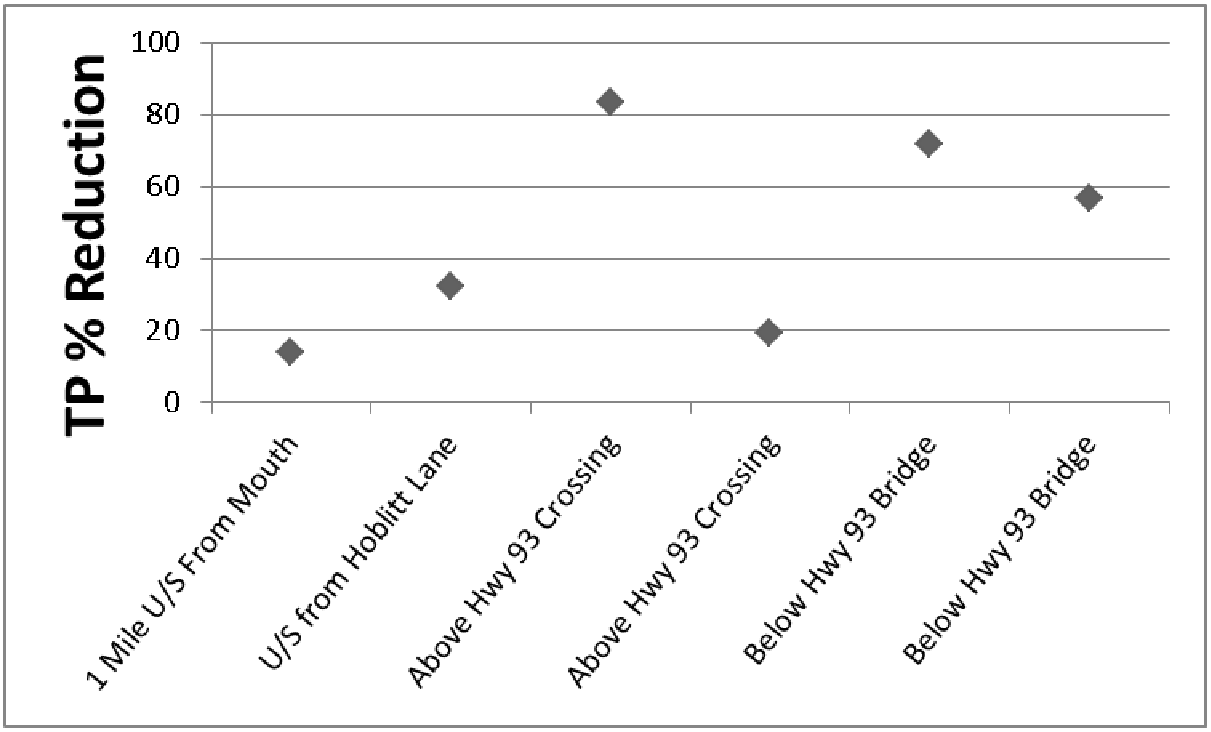


Figure 5-19. Measured TP Percent Load Reductions for Bass Creek (Each TP target exceedance for a site were plotted.)

5.6.4 North Burnt Fork Creek

North Burnt Fork Creek begins in the Sapphire Mountains on the east side of the Bitterroot Valley. The assessment unit includes 10.9 miles of stream from South Burnt Fork Creek to its confluence with the Bitterroot River. The assessment unit flows through all privately-owned lands. watershed.

5.6.4.1 Assessment of Water Quality Results

The source assessment for North Burnt Fork Creek consists of an evaluation of TN and TP concentrations, followed by an estimation of the most significant human-caused sources of nutrients.

Figure 5-20 presents the approximate locations of data pertinent to the source assessment in the North Burnt Fork Creek watershed.

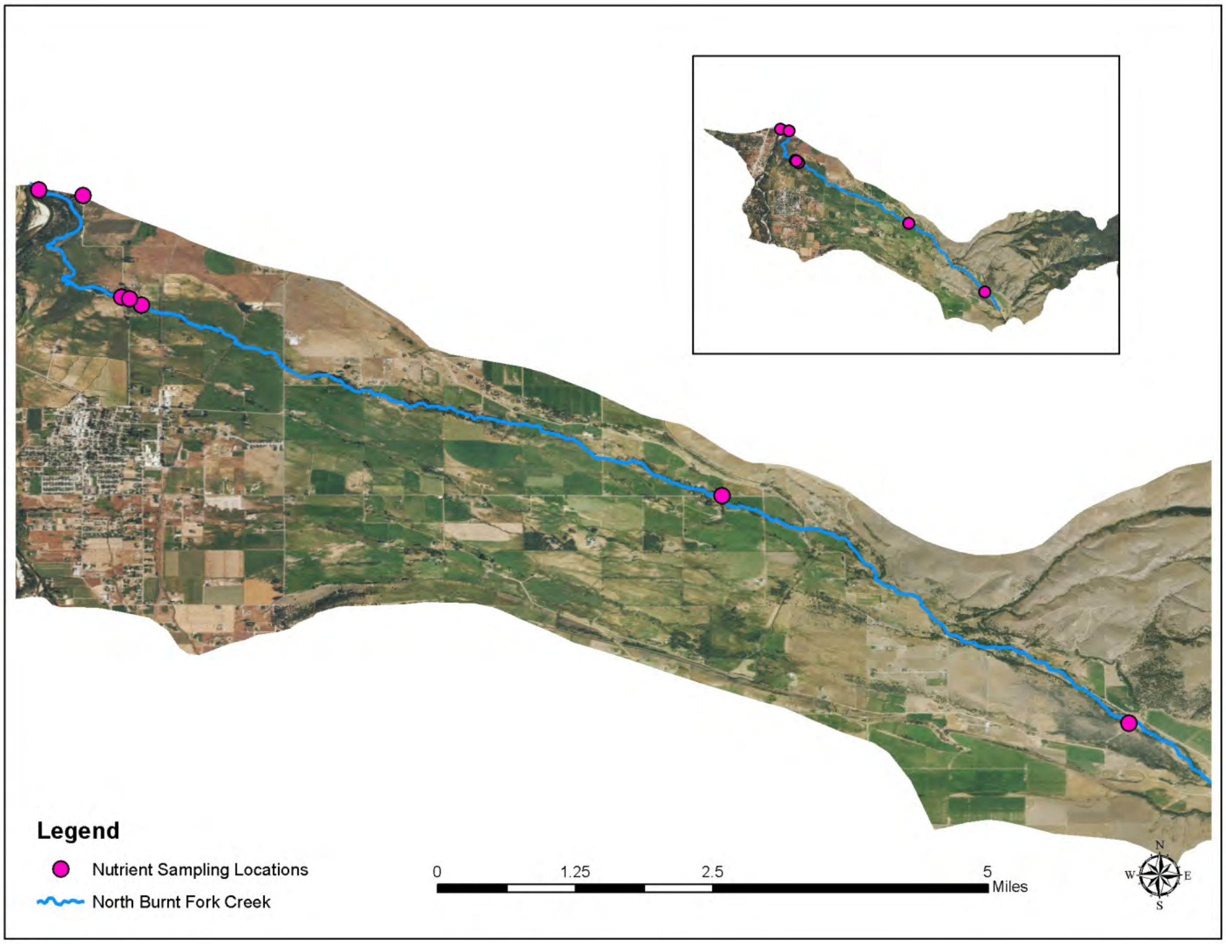


Figure 5-20. North Burnt Fork Creek Watershed with Water Quality Sampling Locations

Total Nitrogen

DEQ collected water quality samples for TN from North Burnt Fork Creek during the growing season between 2007 and 2012 (**Section 5.4.3.5, Table 5-13**). Out of nine total samples, one exceeded the TN target of 0.300 mg/L. The exceedance for North Burnt Fork Creek occurred in the lower reach below the Wildfowl Lane Bridge Crossing (approximately 1.65 miles upstream of the confluence with the Bitterroot River) in an area with agricultural influence. **Figure 5-21** presents summary statistics for TN concentrations at sampling sites in North Burnt Fork Creek.

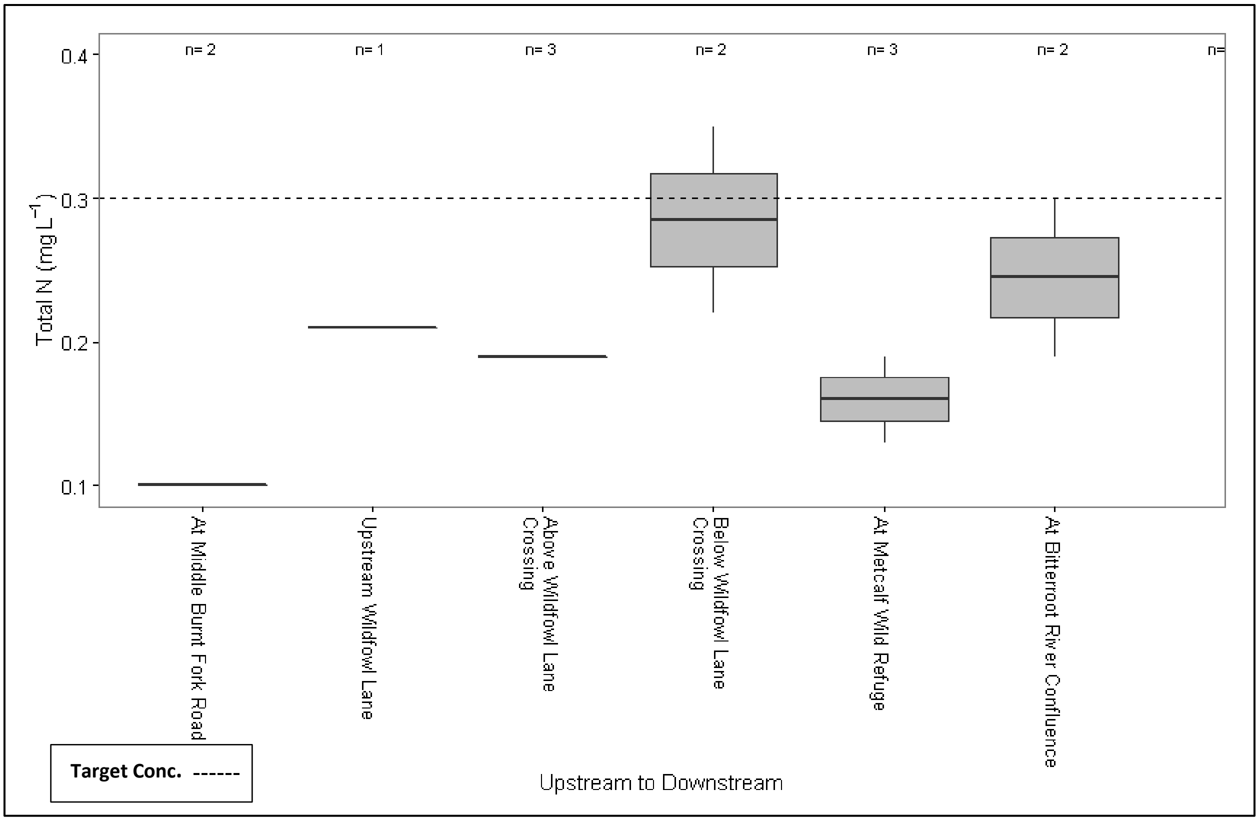


Figure 5-21. Boxplots of TN Concentrations in North Burnt Fork Creek (2007-2012)

Total Phosphorus

DEQ collected water quality samples for TP from North Burnt Fork Creek during the growing season between 2005 and 2012 (**Section 5.4.3.5, Table 5-13**). Out of 13 total samples, 8 exceeded the TP target of 0.03 mg/L. The first of the exceedances for North Burnt Fork Creek occurred on the lower reach, upstream of Wildfowl Lane, in an area with agricultural influence. The remaining exceedances occurred downstream starting at the monitoring location below the Wildfowl Lane Crossing. From below the Wildfowl Lane Crossing, the concentrations generally increase in the downstream direction to the confluence with the Bitterroot River. **Figure 5-22** presents summary statistics for TP concentrations at sampling sites in North Burnt Fork Creek.

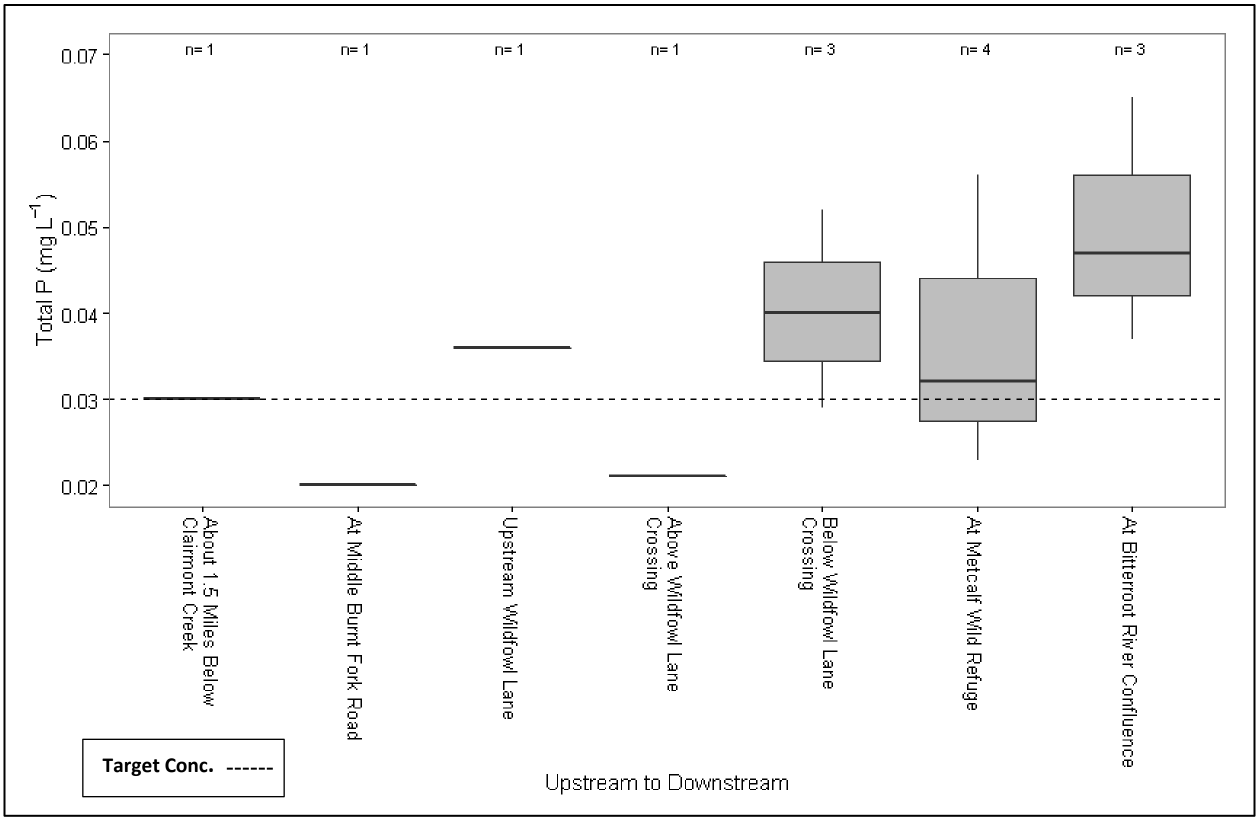


Figure 5-22. Boxplots of TP Concentrations in North Burnt Fork Creek (2005-2012)

5.6.4.2 Source Assessment

The majority of the North Burnt Fork Creek watershed is on private lands with a very small portion of the upper watershed located on USFS land. North Burnt Fork Creek flows through grassland, agricultural (irrigated crop and pasture), and low intensity residential land uses.

A sediment TMDL for North Burnt Fork Creek was completed in 2011 (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011a). As part of sediment TMDL development, DEQ performed stream assessments at two sites along North Burnt Fork Creek in 2007. In the upper assessment reach, field crews noted that the stream flowed through a rural-residential area and that overwidening and bank erosion was occurring. In the lower assessment reach, field crews noted that the streamflows through an area that was actively being used for grazing and had pugging and hummocking. It appeared that the channel was slightly overwidened with extensive streambank erosion, bare ground, and exposed banks where grazing was occurring. An assessment of riparian condition and near-stream land uses that were rated as fair or poor condition (94% of the streambank) were in areas dominated by rural farms and agricultural and hay/pasture lands. Suspected pollutant sources included grazing in riparian zones and irrigated crop production. The land use activities that are increasing sediment supply to North Burnt Fork Creek are also likely linked to an increased nutrient supply in the creek.

Potential human sources that could contribute TP and TN to North Burnt Fork Creek are agriculture (irrigated crops and grazing/pasture), urban development, septic, silvicultural activities, and historic mining; the primary land use and most likely significant nutrient source in North Burnt Fork Creek is agriculture. Each of the potential human sources is discussed below, followed by an analysis of the sources.

Agriculture

The primary land use and the most likely significant nutrient source in the North Burnt Fork Creek watershed is agriculture, which includes irrigated cropland and grazing/pasture. Land used for pasture and hay production is found throughout the entire stream length. Irrigated cropland includes primarily hay and alfalfa, with small acreages of corn, potatoes, and small grains (winter wheat).

Recent field observations indicate evidence of livestock grazing in the stream channel and along its riparian corridor. There is cattle access to the stream and small confined pens of cattle and horses were observed. The stream channel had very little to no riparian and there were signs of livestock-caused hummocks and bank erosion with noticeable early spring algal growth. There are no active grazing permits on the USFS administered portion of the watershed, so the only livestock grazing influence is on private lands.

From geospatial database information, there are numerous small irrigation withdrawals from North Burnt Fork Creek along the entire stream reach. Within the watershed and including livestock sources, irrigation return flows from overland runoff and groundwater recharge in the lower drainage may be likely flow pathways by which nutrients are reaching North Burnt Fork Creek.

Subsurface Wastewater Treatment and Disposal

According to DEQ information, there are numerous individual septic systems in the North Burnt Fork Creek watershed. All of the individual septic systems are concentrated in the valley area, in the downstream part of the watershed, and in some places the septic density is over 100 septic units per square mile. There are a number of systems within close proximity (<100 ft) to the stream. These systems are likely part of the total nutrient loads into the creek.

Silviculture

The majority of the land cover in the North Burnt Fork Creek watershed is agricultural lands and residential development. The Claremont Creek drainage, which drains into North Burnt Fork Creek is forested and an analysis of aerial imagery and geospatial land cover data shows several parcels of recently harvested forest and aerial images show several logging roads in the watershed. Contributions of nutrients to North Burnt Fork Creek from silviculture are likely insignificant.

Mining

According to DEQ and MBMG databases, lode mining occurred in the Burnt Fork district located in the Burnt Fork Bitterroot River watershed, which eventually drains into the Burnt Fork Bitterroot River, just above the North Burnt Fork Creek confluence. There are six abandoned mines listed in the watershed, but the mining in the area has been insignificant. Little is known about the mining in this area, but one of the mines, the Claremont Mine, was a copper lode mine with no records of production. Two barium mines and one iron and silicon mine are located in the Slocum Creek drainage, which drains to the Burnt Fork Bitterroot River. Two copper lode mines, including the Claremont Mine, and an unnamed barium mine are located in the Claremont Creek drainage, which drains to the Burnt Fork Bitterroot.

As the NO_3+NO_2 and TN concentrations are well below targets in the sampling location below the confluence with Claremont Creek, the historic mining activities do not provide a clear linkage as a source of nutrients in North Burnt Fork Creek. In addition, given the distance of the mines from North Burnt Fork Creek, the historic mines do not appear to be having a discernible effect on instream water quality.

5.6.4.3 TN TMDL, Allocations, and Current Loading

The TMDL for TN is based on **Equation 5** and the TMDL allocations are based on **Equation 6.** The value of the TN TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. The following example TN TMDL for North Burnt Fork Creek uses **Equation 5** with the median measured flow from all sites during 2007-2012 sampling (2.37 cfs):

TMDL = (0.300 mg/L) (2.37 cfs) (5.4) = 3.84 lbs/day

Equation 7 is the basis for the natural background load allocation for TN. To continue with the example at a flow of 2.37 cfs, this allocation is as follows:

$$LA_{NB} = (0.095 \text{ mg/L}) (2.37 \text{ cfs}) (5.4) = 1.22 \text{ lbs/day}$$

Using **Equation 8**, the human-caused TN load allocation at 2.37 cfs can be calculated:

$$LA_{H} = 3.84 \text{ lbs/day} – 1.22 \text{ lbs/day} = 2.62 \text{ lbs/day}$$

An example total existing load is based on **Equation 9**, and is calculated as follows using the median of TN target exceedance values measured from North Burnt Fork Creek from 2007-2012 (0.350 mg/L) and the median measured flow of 2.37 cfs:

Total Existing Load = (0.350 mg/L) (2.37 cfs) (5.4) = 4.48 lbs/day

The portion of the total existing load attributed to human sources is 3.26 lbs/day, which is determined by subtracting out the 1.22 lbs/day background load. This 3.26 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-34 contains the results for the example TN TMDL, LAs, and current loading. In addition, it contains an example percent reduction to the human-caused LA required to meet the water quality target for TN. At the median growing season flow of 2.37 cfs, and the median of measured TN target exceedance values, the current loading in North Burnt Fork Creek is greater than the TMDL. Under these example conditions, a 20% reduction of human-caused TN loads, which results in an overall 14% reduction of TN in North Burnt Fork Creek, would result in the TMDL being met. The source assessment of the North Burnt Fork Creek watershed indicates that agriculture is the most likely source of TN in North Burnt Fork Creek; load reductions should focus on limiting and controlling TN loading from these sources. Meeting LAs for North Burnt Fork Creek may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 9.4.1**.

Table 5-34. North Burnt Fork Creek TN Example TMDL, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction
Natural Background	1.22	1.22	0%
Human-caused (primarily agriculture)	2.62	3.26	20%
	TMDL = 3.84	**Total = 4.48**	**Total = 14%**

[1]Based on a median growing season flow of 2.37 cfs

Figure 5-23 shows the percent reductions for TN loads measured in North Burnt Fork Creek from 2007-2012. Because flow data were absent for some of the water quality samples, percent reductions were calculated for the sampling locations where the measured TN concentrations were above the target. Any time concentration exceeds the target, the corresponding load, even if flow is not measured, exceeds the TMDL since the TMDL equation is based on concentration multiplied by the flow. Loads greater than the TMDL require reductions, so percent reductions in TN loads are the same as percent reductions in TN concentrations. Based on the results presented in **Figure 5-23**, there was only one TN target exceedance, so the overall reduction is 14% to meet the TMDL.

Figure 5-23. Measured TN Percent Load Reductions for North Burnt Fork Creek (Each TN target exceedance for a site were plotted.)

5.6.4.4 TP TMDL, Allocations, and Current Loading

The TMDL for TP is based on **Equation 5** and the TMDL allocations are based on **Equation 6.** The value of the TP TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. The following example TP TMDL for North Burnt Fork Creek uses **Equation 5** with the median measured flow from all sites during 2005-2012 sampling (2.37 cfs):

$$\textbf{TMDL = (0.030 mg/L) (2.37 cfs) (5.4) = 0.384lbs/day}$$

Equation 7 is the basis for the natural background load allocation for TP. To continue with the example at a flow of 2.37 cfs, this allocation is as follows:

$$\mathbf{LA_{NB}} \textbf{ = (0.010 mg/L) (2.37 cfs) (5.4) = 0.128 lbs/day}$$

Using **Equation 8**, the human-caused TP load allocation at 2.37 cfs can be calculated:

$$\mathbf{LA_H = 0.384\ lbs/day - 0.128\ lbs/day = 0.256\ lbs/day}$$

An example total existing load is based on **Equation 9**, and is calculated as follows using the median of TP target exceedance values measured from North Burnt Fork Creek from 2005-2012 (0.0435 mg/L) and the median measured flow of 2.37 cfs:

Total Existing Load = (0.0435 mg/L) (2.37 cfs) (5.4) = 0.557 lbs/day

The portion of the total existing load attributed to human sources is 0.429 lbs/day, which is determined by subtracting out the 0.128 lbs/day background load. This 0.429 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-35 contains the results for the example TP TMDL, LAs, and current loading. In addition, it contains an example percent reduction to the human-caused LA required to meet the water quality target for TP. At the median growing season flow of 2.37 cfs, and the median of measured TP target exceedance values, the current loading in North Burnt Fork Creek is greater than the TMDL. Under these example conditions, a 40% reduction of human-caused TP loads, which results in an overall 31% reduction of TP in North Burnt Fork Creek, would result in the TMDL being met. The source assessment of the North Burnt Fork Creek watershed indicates that agriculture is the most likely source of TP in North Burnt Fork Creek; load reductions should focus on limiting and controlling TP loading from these sources. Meeting LAs for North Burnt Fork Creek may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 9.4.1**.

Table 5-35. North Burnt Fork Creek TP Example TMDL, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction
Natural Background	0.128	0.128	0%
Human-caused (primarily agriculture)	0.256	0.429	40%
	TMDL = 0.384	**Total = 0.557**	**Total = 31%**

[1]Based on a median growing season flow of 2.37 cfs

Figure 5-24 shows the percent reductions for TP loads measured in North Burnt Fork Creek from 2005-2012. Because flow data were absent for some of the water quality samples, percent reductions were calculated for the sampling locations where the measured TP concentrations were above the target. Any time concentration exceeds the target, the corresponding load, even if flow is not measured, exceeds the TMDL since the TMDL equation is based on concentration multiplied by the flow. Loads greater than the TMDL require reductions, so percent reductions in TP loads are the same as percent reductions in TP concentrations. For North Burnt Fork Creek, there were multiple TP target exceedances from different sampling events for three of the sampling locations, so TP reductions for all exceedances at those sites were calculated and plotted. Based on the results presented in **Figure 5-24**, TP load reductions ranging from 6% to 54%, with a median overall reduction of 31%, are necessary to meet the TMDL.

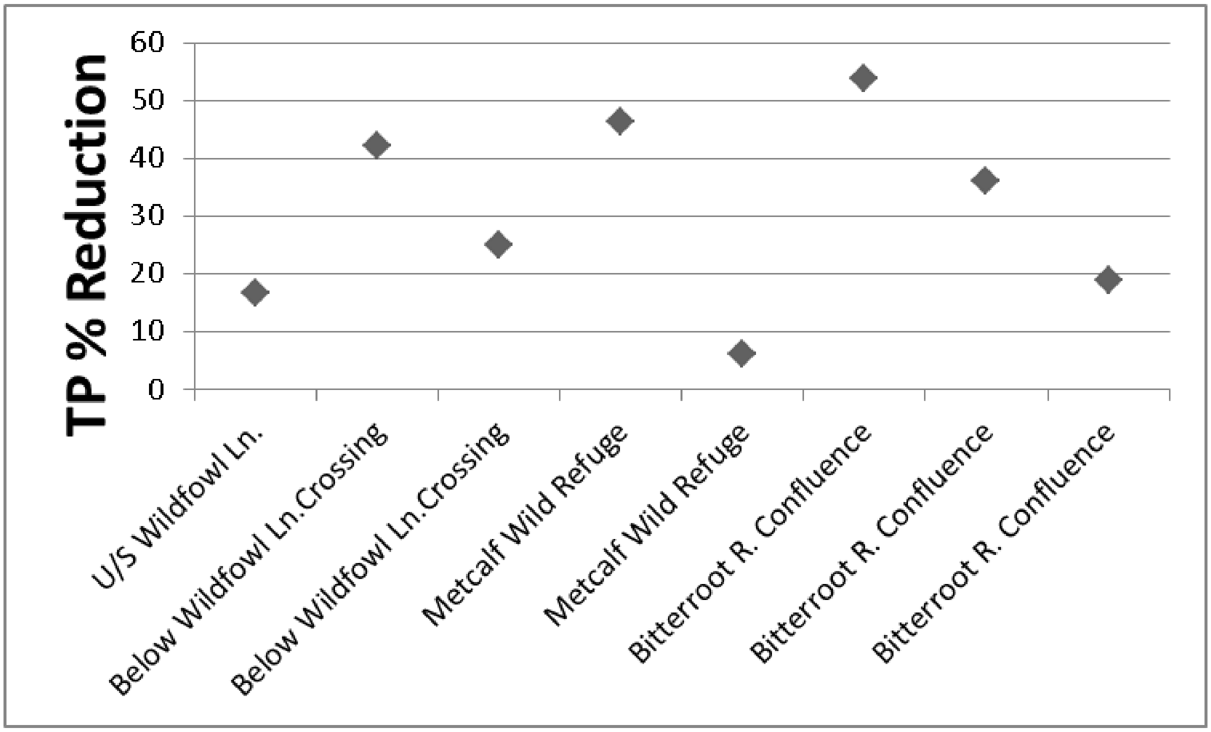


Figure 5-24. Measured TP Percent Load Reductions for North Burnt Fork Creek (Each TP target exceedance for a site were plotted.)

5.6.5 Muddy Spring Creek

Muddy Spring Creek, a tributary to Gold Creek, begins in the Sapphire Mountains on the east side of the Bitterroot Valley and flows 2.0 miles to its confluence with Gold Creek. The entire segment of the creek is within the Bitterroot National Forest.

5.6.5.1 Assessment of Water Quality Results

The source assessment for Muddy Spring Creek consists of an evaluation of NO_3+NO_2 concentrations, followed by an estimation of the most significant human-caused sources of nutrients. **Figure 5-25** presents the approximate locations of data pertinent to the source assessment in the Muddy Spring Creek watershed.

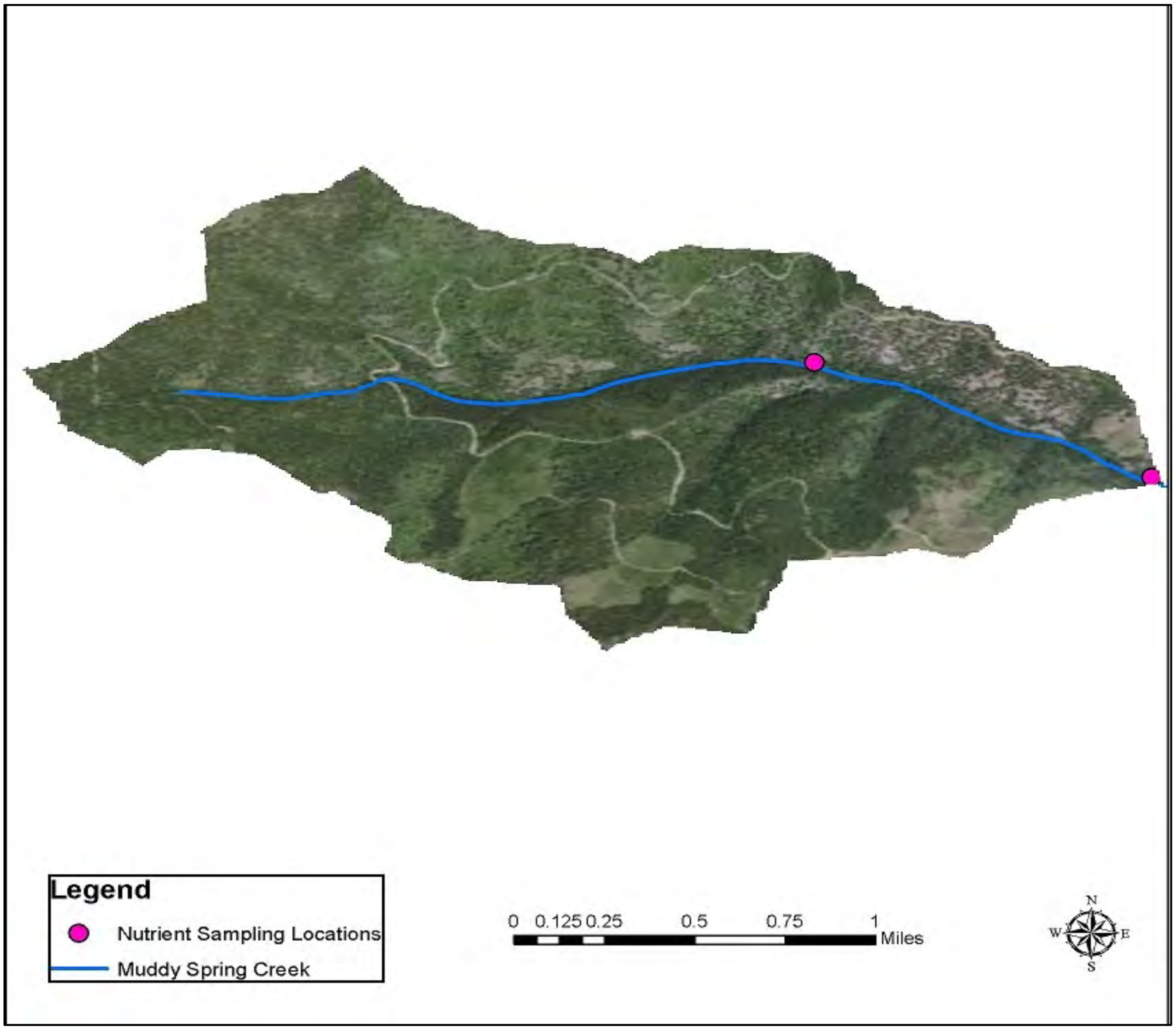


Figure 5-25. Muddy Spring Creek Watershed with Water Quality Sampling Locations

Nitrate + Nitrite

DEQ collected water quality samples for NO_3+NO_2 from Muddy Spring Creek during the growing season between 2004 and 2012 (**Section 5.4.3.4, Table 5-9**). Out of four total samples, all exceeded the NO_3+NO_2 target of 0.100 mg/L. **Figure 5-26** presents summary statistics for NO_3+NO_2 concentrations at sampling sites in Muddy Spring Creek.

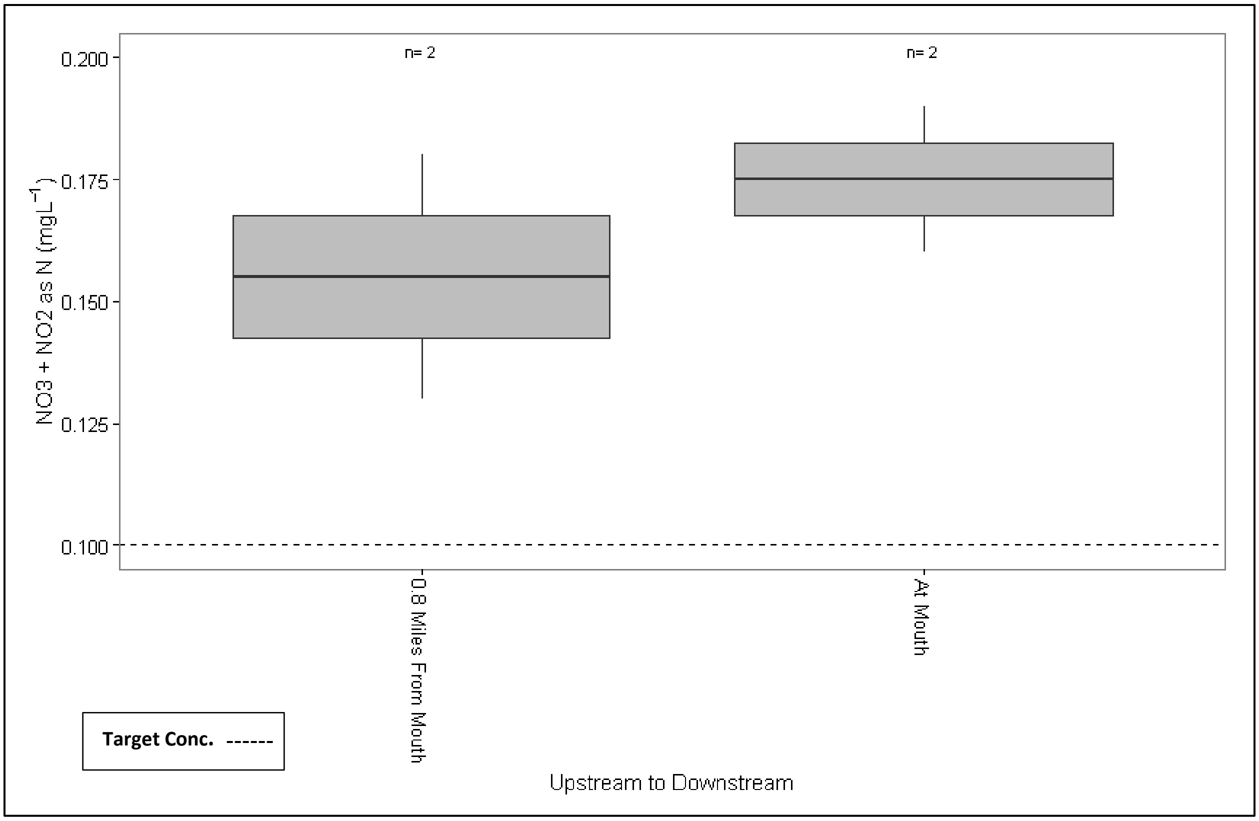


Figure 5-26. Boxplots of NO_3+NO_2 Concentrations in Muddy Spring Creek (2004 and 2012)

5.6.5.2 Source Assessment

All of Muddy Spring Creek drains forest land cover with the majority managed within the Bitterroot National Forest. Land cover shows recently burned forest on the southeast corner of the watershed, and harvest activities in the past 10 years also on the southern part of the watershed.

A sediment TMDL for Muddy Spring Creek was completed in 2011 (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011a), and rangeland grazing was the suspected pollutant source. Observations from 2007 riparian assessments by DEQ for TMDL development suggested that Muddy Spring Creek is recovering from historic management practices.

Potential human sources that could contribute NO_3+NO_2 to Muddy Spring Creek are grazing and silvicultural activities. Each of the potential human sources is discussed below, followed by an analysis of the sources.

Agriculture

Occupying a large portion of the Muddy Spring Creek watershed, the Gold Creek grazing allotment comprises 2,583 acres on USFS administered lands with an average number of 53 permitted AUMs (**Table 5-24**) on the allotment in any given year. The allotment encompasses land in several watersheds, with 837 acres of the total allotment in the Muddy Spring Creek watershed; however, the allotment has not been grazed since 2007.

Subsurface Wastewater Treatment and Disposal
According to DEQ records, there are no septic systems in the Muddy Spring Creek watershed.

Silviculture
An analysis of aerial imagery and geospatial land cover data shows several parcels of recently burned and recently harvested forest in the watershed. There is a network of four wheel drive and light duty roads, but there is only one road crossing on the stream. There have been several forest management activities in the southern portion of the Muddy Spring Creek watershed in the past 10 years according to GIS information provided by the Bitterroot National Forest, although these operations are not within close proximity to the stream channel.

Mining
According to DEQ and MBMG databases, no historic mining has occurred in the Muddy Spring Creek watershed.

5.6.5.3 NO_3+NO_2 TMDL, Allocations, and Current Loading

The TMDL for NO_3+NO_2 is based on **Equation 5** and the TMDL allocations are based on **Equation 6.** The value of the NO_3+NO_2 TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. The following example NO_3+NO_2 TMDL for Muddy Spring Creek uses **Equation 5** with the median measured flow from all sites during 2004 and 2012 sampling (0.22 cfs):

TMDL = (0.100 mg/L) (0.22 cfs) (5.4) = 0.119 lbs/day

Equation 7 is the basis for the natural background load allocation for TN. To continue with the example at a flow of 0.22 cfs, this allocation is as follows:

LA_{NB} = (0.02 mg/L) (0.22 cfs) (5.4) = 0.024 lbs/day

Using **Equation 8**, the human-caused TN load allocation at 0.93 cfs can be calculated:

LA_H = 0.119 lbs/day – 0.024 lbs/day = 0.095 lbs/day

An example total existing load is based on **Equation 9**, and is calculated as follows using the median of NO_3+NO_2 target exceedance values measured from Muddy Spring Creek from 2004 and 2012 (0.17 mg/L) and the median measured flow of 0.22 cfs:

Total Existing Load = (0.17 mg/L) (0.22 cfs) (5.4) = 0.202 lbs/day

The portion of the total existing load attributed to human sources is 0.178 lbs/day, which is determined by subtracting out the 0.024 lbs/day background load. This 0.178 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-36 contains the results for the example NO_3+NO_2 TMDL, LAs, and current loading. In addition, it contains an example percent reduction to the human-caused LA required to meet the water quality target for NO_3+NO_2. At the median growing season flow of 0.22 cfs, and the median of measured NO_3+NO_2 target exceedance values, the current loading in Muddy Spring Creek is greater than the TMDL. Under these example conditions, a 47% reduction of human-caused NO_3+NO_2 loads, which results in an overall 41% reduction of NO_3+NO_2 in Muddy Spring Creek, would result in the TMDL being met. The source assessment of the Muddy Spring Creek watershed indicates that grazing and silviculture are the most likely sources of NO_3+NO_2 in Muddy Spring Creek; load reductions should focus on limiting and controlling NO_3+NO_2 loading from these sources. Meeting LAs for Muddy Spring Creek may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 9.4.1**.

Table 5-36. Muddy Spring Creek NO_3+NO_2 Example TMDL, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction
Natural Background	0.024	0.024	0%
Human-caused (primarily grazing and silviculture)	0.095	0.178	47%
	TMDL = 0.119	**Total = 0.202**	**Total = 41%**

[1]Based on a median growing season flow of 0.22 cfs

Figure 5-27 shows the percent reductions for NO_3+NO_2 loads measured in Muddy Spring Creek in 2004 and 2012. Because flow data were absent for some of the water quality samples, percent reductions were calculated for the sampling locations where the measured NO_3+NO_2 concentrations were above the target. Any time concentration exceeds the target, the corresponding load, even if flow is not measured, exceeds the TMDL since the TMDL equation is based on concentration multiplied by the flow. Loads greater than the TMDL require reductions, so percent reductions in NO_3+NO_2 loads are the same as percent reductions in NO_3+NO_2 concentrations. There were two NO_3+NO_2 target exceedances from different sampling events at both sampling locations on Muddy Spring Creek, so both NO_3+NO_2 reductions for each site were calculated and plotted. Based on the results presented in **Figure 5-27**, NO_3+NO_2 load reductions ranging from 23% to 47%, with a median overall reduction of 41%, are necessary to meet the TMDL.

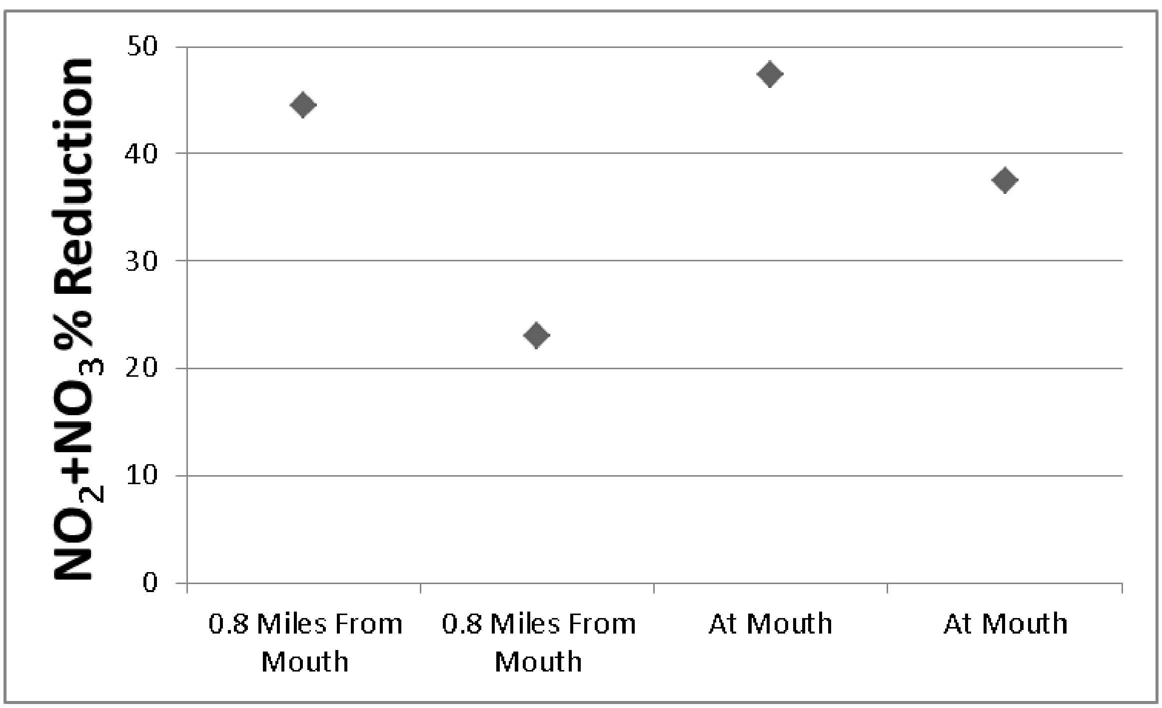


Figure 5-27. Measured NO_3+NO_2 Percent Load Reductions for Muddy Spring Creek (Each NO_3+NO_2 target exceedance for a site were plotted.)

5.6.6 Sweathouse Creek

Sweathouse Creek begins in the Bitterroot Mountains on the west side of the Bitterroot Valley and flows 11.6 miles from the headwaters to its confluence with the Bitterroot River. The headwaters of the stream are dominated by Bitterroot National Forest lands, while the lower reaches are bordered by private lands.

5.6.6.1 Assessment of Water Quality Results

The source assessment for Sweathouse Creek consists of an evaluation of TP concentrations, followed by an estimation of the most significant human-caused sources of nutrients. **Figure 5-28** presents the approximate locations of data pertinent to the source assessment in the Sweathouse Creek watershed.

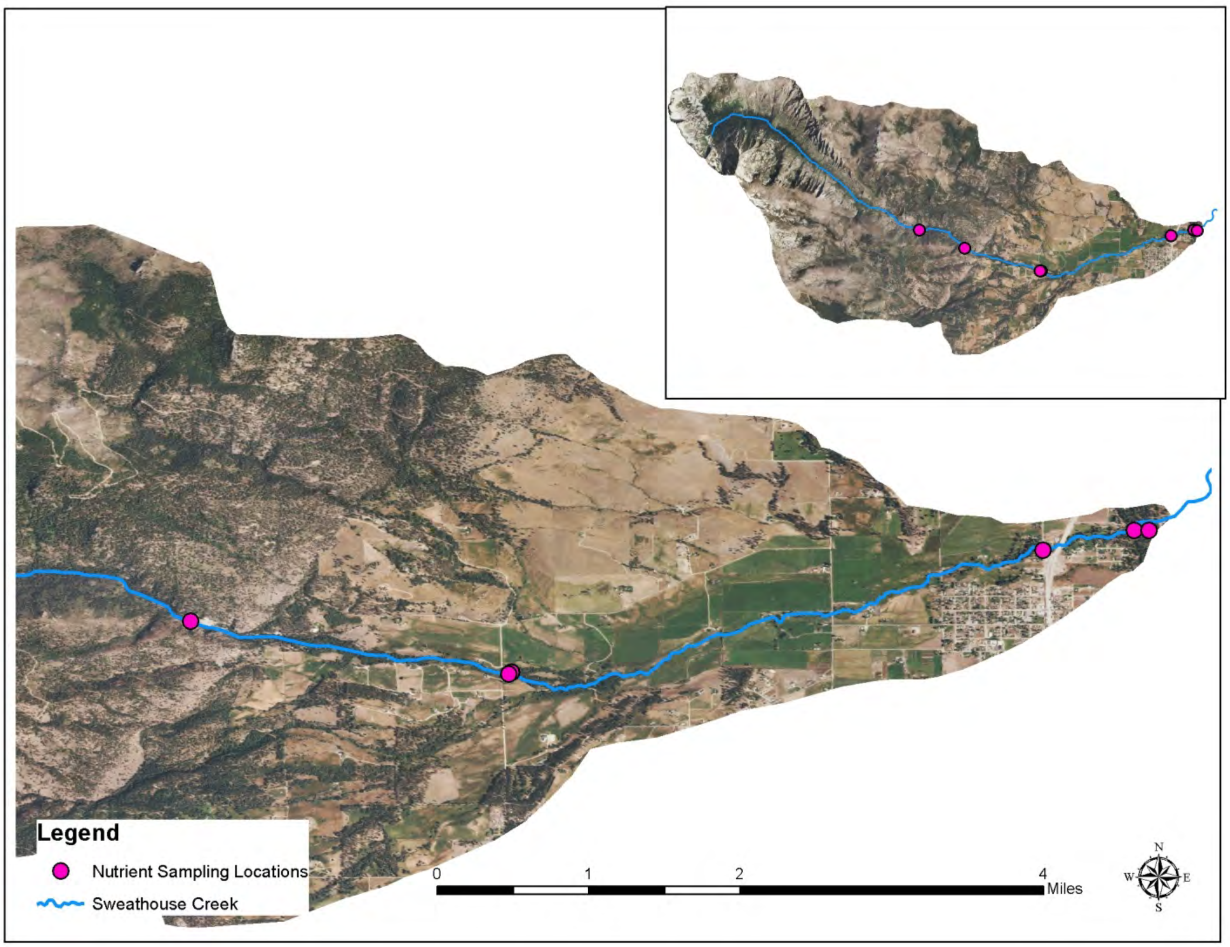


Figure 5-28. Sweathouse Creek Watershed with Water Quality Sampling Locations

Total Phosphorus

DEQ collected water quality samples for TP from Sweathouse Creek during the growing season between 2006 and 2012 (**Section 5.4.3.8, Table 5-17**). Out of 16 total samples, 6 exceeded the TP target of 0.025 mg/L. The first of the exceedances for Sweathouse Creek occurred in the lower reach at the Highway 93 crossing and the concentrations increase near the mouth, with all samples at the Highway 93 Crossing and Near Mouth sampling locations exceeding the target. **Figure 5-29** presents summary statistics for TP concentrations at sampling sites in Sweathouse Creek.

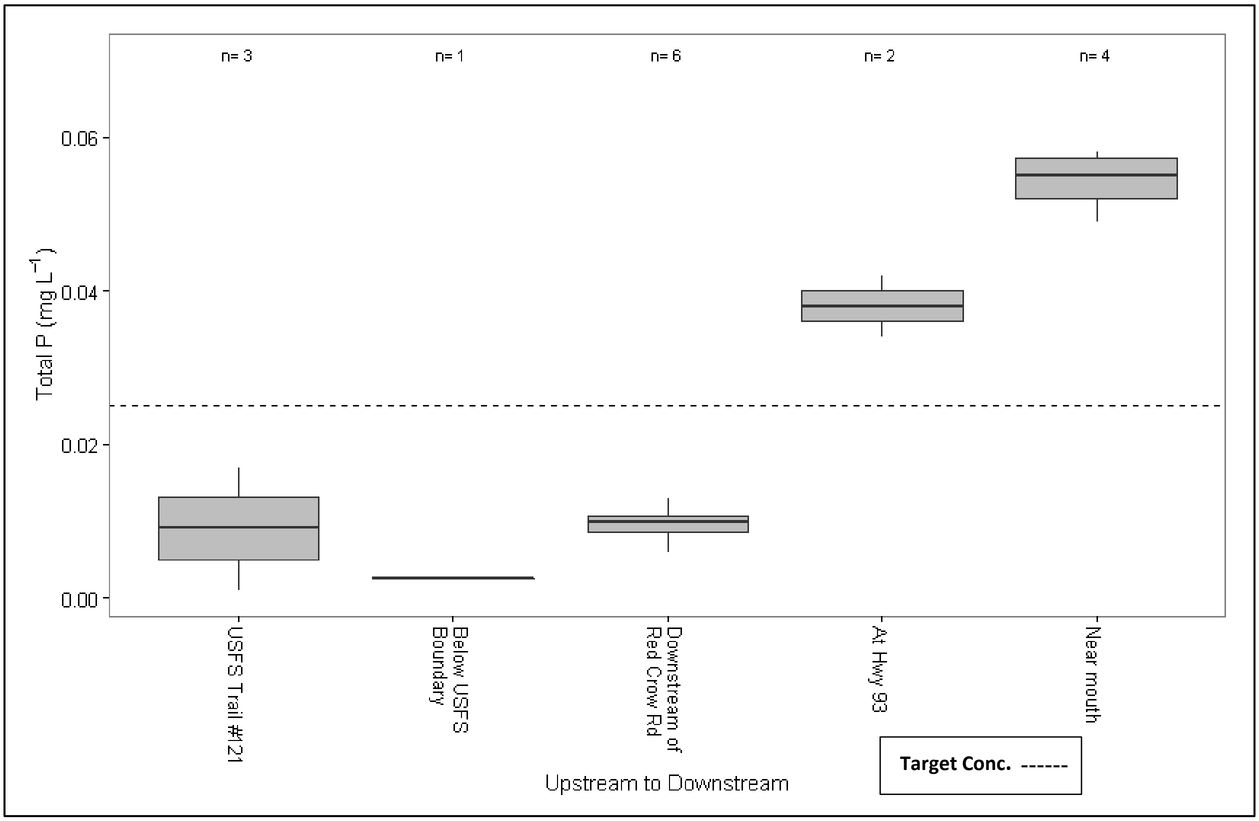


Figure 5-29. Boxplots of TP Concentrations in Sweathouse Creek (2006-2012)

5.6.6.2 Source Assessment

The headwaters of Sweathouse Creek encompass Bitterroot National Forest lands, while the lower reaches are bordered by private lands where the land use is agricultural with urban development around the town of Victor, MT.

A sediment TMDL for Sweathouse Creek was completed in 2011 (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011a). As part of sediment TMDL development, DEQ performed a stream assessment at one site along the creek in 2007. The assessment reach was located on private land in the lower watershed and the field assessment crew noted that it was entrenched in places with eroding streambanks. An assessment of riparian condition and near-stream land uses that were rated as fair or poor condition (38% of the streambank) were in areas dominated by pasture and small rural farms and the few willows were heavily browsed. The land use activities that are increasing sediment supply to Sweathouse Creek are also likely linked to an increased nutrient supply in the creek.

The last two miles on Sweathouse Creek, from downstream of Pleasant View Drive to the mouth, is on the Montana Fish, Wildlife and Parks Dewatered Streams List as being chronically dewatered. The list refers to streams that are significantly reduced in streamflow to the point where fish are seriously impacted.

Potential human sources that could contribute TP to Sweathouse Creek are agriculture (irrigated crops and grazing/pasture), urban development, septic, silvicultural activities, and historic mining; the primary land uses and most likely significant nutrient sources in Sweathouse Creek are agriculture and septic. Each of the potential human sources is discussed below, followed by an analysis of the sources.

Agriculture

Agriculture land use is substantial in the Sweathouse Creek watershed below the USFS boundary. The valley portion of the watershed above Victor is used extensively for irrigated crops (hay and alfalfa) and grazing/pasture. There are cattle ranches and an increasing number of small acreage pasture units in the lower part of the Sweathouse Creek watershed. Recent field observations indicated evidence of livestock grazing in the stream channel with cattle access to the stream and along the riparian corridor. In addition, small pasture units of cattle and horses were observed. There were portions of the stream where there was a significant loss of riparian and noticeable early spring algal growth. In addition, grazing allotments comprise 1,015 of acres on USFS administered lands in the watershed with an average number of 16 permitted AUMs on the allotment in any given year (**Table 5-24**).

From database information, there are a number of small irrigation withdrawals from Sweathouse Creek below the forest boundary. Within the watershed and including livestock sources, irrigation return flows from overland runoff and groundwater recharge in the lower watershed are likely flow pathways by which nutrients are reaching Sweathouse Creek.

Subsurface Wastewater Treatment and Disposal

Sweathouse Creek flows through the town of Victor. The Victor wastewater treatment system consists of lagoons, and sludge is land applied at agronomic uptake rates and therefore does not need a Montana Ground Water Pollution Control System (MGWPCS) permit. According to DEQ information, there are a large number of individual septic systems in the Sweathouse Creek watershed. All of the individual septics are scattered across the valley, and in some areas the drainfield density is 26-50 septic units per square mile. There are a relative few within close proximity (<100 ft) to the stream, so septic effluent may be a contributor to the existing Sweathouse Creek TP load.

Silviculture

An analysis of aerial imagery and geospatial land cover data shows parcels of land with recently burned and recently harvested forest on both sides of the creek in the forested lands of the watershed. In 2006, the Gash forest fire burned approximately 10,000 acres, which encompassed a majority of the forested lands in the Sweathouse Creek watershed. According to geospatial information provided by the USFS, there have been some recent forest management/harvest activities in the past 10 years on several parcels on both sides of the drainage. Aerial images show several unpaved forestry roads in the watershed, although none are within close proximity to the stream. Based on the boxplots of the TP data, contributions of nutrients to Sweathouse Creek from silviculture are likely insignificant.

Mining

According to DEQ and MBMG databases, there are two abandoned mines listed in the Sweathouse Creek watershed. A former titanium, iron, zirconium, and thorium placer mine is located 3 miles from the mouth while a gold and silver mine is located in the Town of Victor. There is no clear linkage between these historic mining activities and nutrient loads to Sweathouse Creek.

In addition, aerial images show a granite rock quarry on Sweathouse Creek below the USFS Boundary; although this facility does not have a discharge permit, it is in close proximity to the stream and may be a potential contributor of sediment loads to the stream. Based on the boxplots of the data, contributions of TP to Sweathouse Creek from mining are likely insignificant.

5.6.6.3 TP TMDL, Allocations, and Current Loading

The TMDL for TP is based on **Equation 5** and the TMDL allocations are based on **Equation 6.** The value of the TP TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. The following example TP TMDL for Sweathouse Creek uses **Equation 5** with the median measured flow from all sites during 2006-2012 sampling (2.34 cfs):

TMDL = (0.025 mg/L) (2.34 cfs) (5.4) = 0.316 lbs/day

Equation 7 is the basis for the natural background load allocation for TP. To continue with the example at a flow of 2.34 cfs, this allocation is as follows:

LA_{NB} = (0.006 mg/L) (2.34 cfs) (5.4) = 0.076 lbs/day

Using **Equation 8**, the human-caused TP load allocation at 2.34 cfs can be calculated:

LA_{H} = 0.316 lbs/day – 0.076 lbs/day = 0.240 lbs/day

An example total existing load is based on **Equation 9**, and is calculated as follows using the median of TP target exceedance values measured from Sweathouse Creek from 2006-2012 (0.051 mg/L) and the median measured flow of 2.34 cfs:

Total Existing Load = (0.051mg/L) (2.34 cfs) (5.4) = 0.644 lbs/day

The portion of the total existing load attributed to human sources is 0.569 lbs/day, which is determined by subtracting out the 0.076 lbs/day background load. This 0.569 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-37 contains the results for the example TP TMDL, LAs, and current loading. In addition, it contains an example percent reduction to the human-caused LA required to meet the water quality target for TP. At the median growing season flow of 2.34 cfs, and the median of measured TP target exceedance values, the current loading in Sweathouse Creek is greater than the TMDL. Under these example conditions, a 58% reduction of human-caused TP loads, which results in an overall 51% reduction of TP in Sweathouse Creek, would result in the TMDL being met. The source assessment of the Sweathouse Creek watershed indicates that agriculture and septic are the most likely sources of TP in Sweathouse Creek; load reductions should focus on limiting and controlling TP loading from these sources. Meeting LAs for Sweathouse Creek may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 9.4.1**.

Table 5-37. Sweathouse Creek TP Example TMDL, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction
Natural Background	0.076	0.076	0%
Human-caused (primarily agriculture and septic)	0.240	0.569	58%
	TMDL = 0.316	**Total = 0.644**	**Total = 51%**

[1]Based on a median growing season flow of 2.34 cfs

Figure 5-30 shows the percent reductions for TP loads measured in Sweathouse Creek from 2006-2012. Because flow data were absent for some of the water quality samples, percent reductions were calculated for the sampling locations where the measured TP concentrations were above the target. Any time concentration exceeds the target, the corresponding load, even if flow is not measured, exceeds the TMDL since the TMDL equation is based on concentration multiplied by the flow. Loads greater than the TMDL require reductions, so percent reductions in TP loads are the same as percent reductions in TP concentrations. For Sweathouse Creek, there were multiple TP target exceedances from different sampling events at the Hwy 93 and Near Mouth sampling locations, so the TP reductions for all exceedances at those sites were calculated and plotted. Based on the results presented in **Figure 5-30**, TP load reductions ranging from 26% to 57%, with a median overall reduction of 51%, are necessary to meet the TMDL.

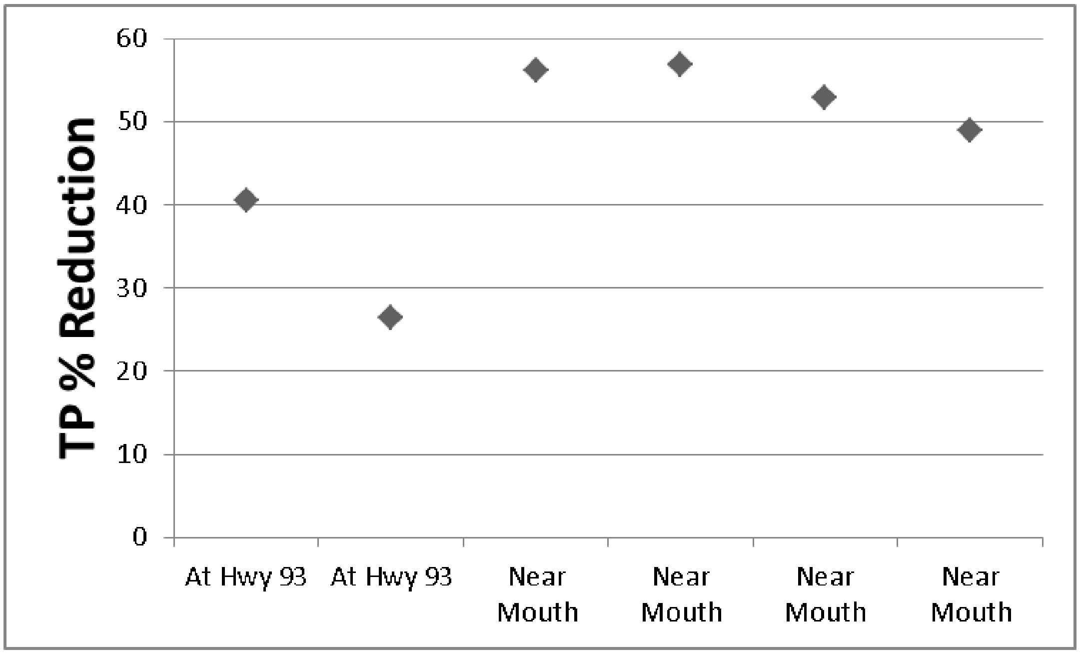


Figure 5-30. Measured TP Percent Load Reductions for Sweathouse Creek (Each TP target exceedance for a site were plotted.)

5.6.7 Lick Creek

Lick Creek begins in the Bitterroot Mountains on the west side of the Bitterroot Valley and flows 6.4 miles to its confluence with the Bitterroot River. Private lands border the stream for approximately one mile before the confluence with the Bitterroot River.

5.6.7.1 Assessment of Water Quality Results

The source assessment for Lick Creek consists of an evaluation of TP concentrations, followed by an estimation of the most significant human-caused sources of nutrients. **Figure 5-31** presents the approximate locations of data pertinent to the source assessment in the Lick Creek watershed.

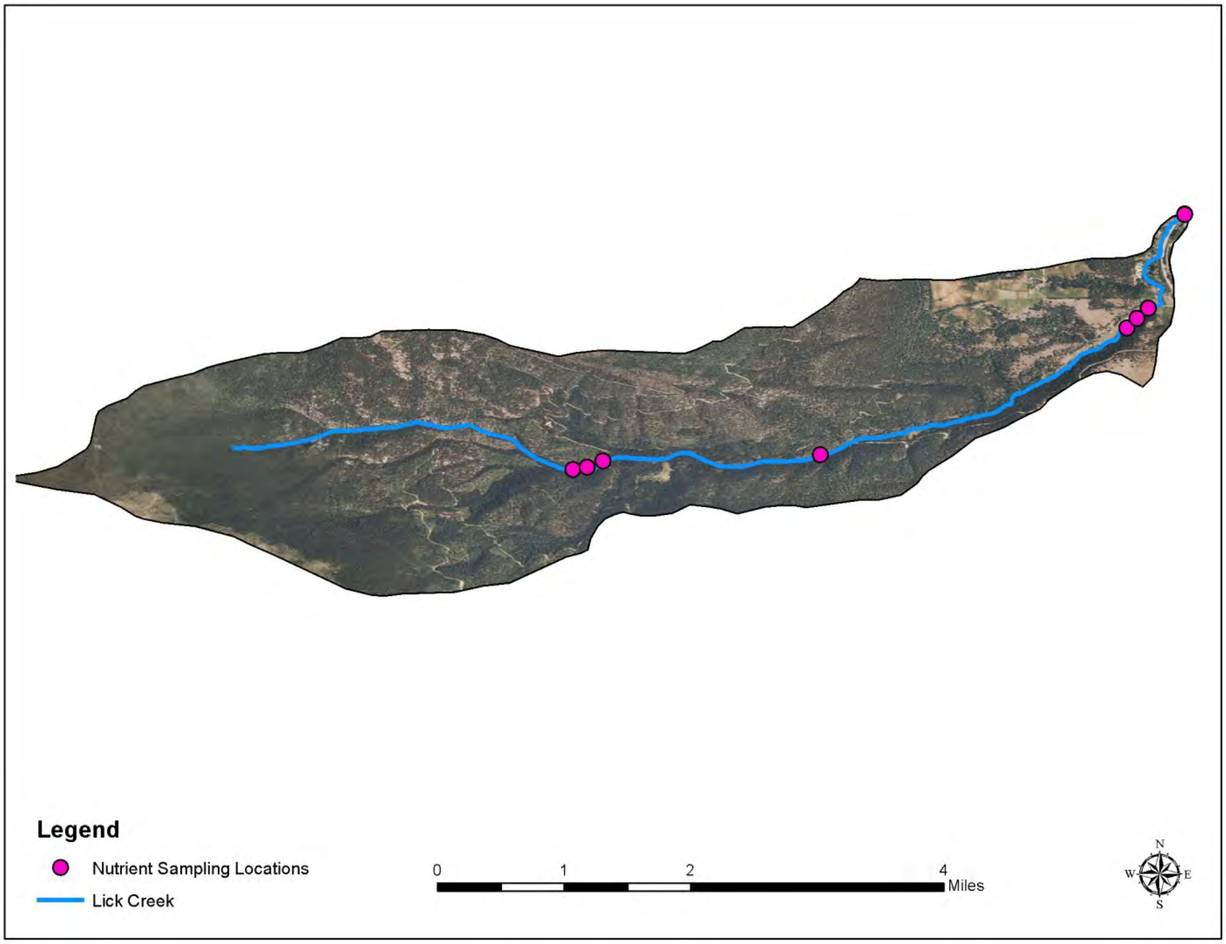


Figure 5-31. Lick Creek Watershed with Water Quality Sampling Locations

Total Phosphorus
DEQ collected water quality samples for TP from Lick Creek during the growing season between 2004 and 2012 (**Section 5.4.3.3, Table 5-7**). Out of 17 total samples, 6 exceeded the TP target of 0.030 mg/L. A single TP exceedance occurred on USFS administered land in 2004, upstream of the Lost Horse Cutoff. There were no other TP exceedances for samples collected on USFS administered land. Moving downstream, the remaining exceedances occurred on the lower reach of Lick Creek. The exceedances occurred between the sampling locations above the Lick Creek Road crossing to the Highway 93 crossing, near the mouth. **Figure 5-32** presents summary statistics for TP concentrations at sampling sites in Lick Creek.

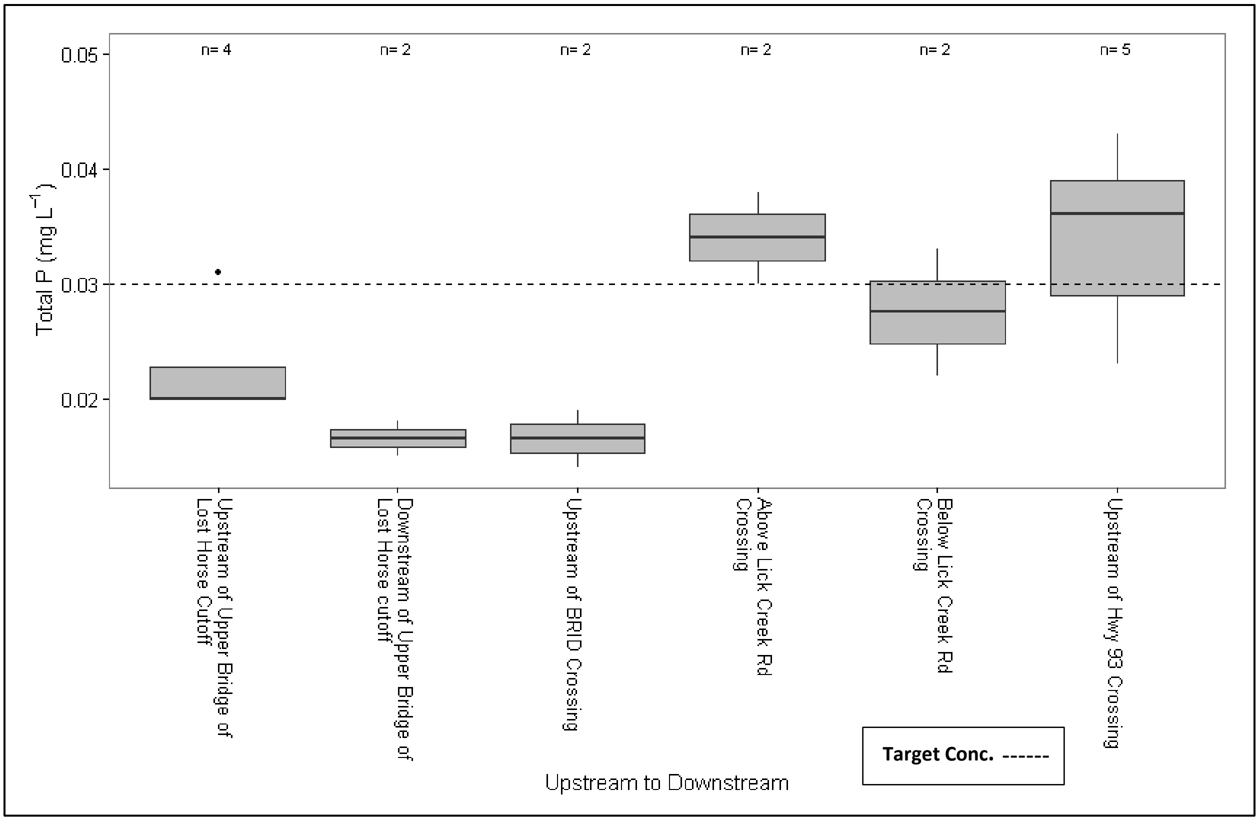


Figure 5-32. Boxplots of TP Concentrations in Lick Creek (2004-2012)

5.6.7.2 Source Assessment

The majority of the Lick Creek watershed includes forest land cover within the Bitterroot National Forest, which includes the Lick Creek Demonstration/Research Forest. Although the majority of the watershed is forested, small properties with hay or pasture exist on privately-owned land downstream of the USFS boundary. Additional privately-owned land in the lower reaches appears in aerial imagery as sparsely vegetated grassland.

A sediment TMDL for Lick Creek was completed in 2011 (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011a). As part of sediment TMDL development, DEQ performed a stream assessment at one site along Lick Creek in 2007, which was located on private land a short distance upstream from Highway 93. According to the stream survey crew, there appeared to be minimal watershed disturbance upstream of this site, though there was a flood irrigated field along the downstream river left of the reach and signs of historic grazing on the hillslopes. In addition, an assessment of the riparian condition was conducted in 2007. The majority of the streambank was rated in good condition while 20% of the streambank was rated in fair or poor condition. Those portions of Lick Creek's riparian areas that were rated as good condition were dominated by forest land uses; while those as fair or poor conditions were dominated by agriculture and significant anthropogenic effects were observed within 100 feet of the channel.

Recent field observations noted what appeared to be a wetland area, a log home construction business, and some mineralized geology off of Highway 93, downstream of the Lick Creek Road Crossing between two of the lower reach monitoring locations. Since there were also exceedances above these noted areas, it is unknown whether they could be contributing to the TP load.

Potential human sources that could contribute TP to Lick Creek are agricultural (irrigated crops and grazing/pasture), septic, and silvicultural activities; the primary land uses and most likely significant human-caused nutrient sources in Lick Creek are agriculture (irrigated crops and grazing/pasture) and silviculture. Each of the potential human sources is discussed below, followed by an analysis of the sources.

Agriculture

The data presented in the boxplots (**Figure 5-32**) indicate that the TP exceedances are typically occurring in the agricultural areas of the watershed. A small portion at the lower end of the Lick Creek watershed consists of agricultural lands comprising of small properties with pasture or irrigated crops (hay and alfalfa). On the lower portion of the watershed, small acreage animal confinement areas and a grazing area in the meadow upstream of the Lick Creek Road crossing was noted during recent field observations.

Occupying a large portion of the middle of Lick Creek, the Trapper Creek grazing allotment comprises 7,455 acres on USFS administered lands with an average number of 75 permitted AUMs (**Table 5-24**) in any given year. The allotment encompasses land in several watersheds, with 2,319 acres of the total allotment in the Lick Creek watershed.

The Lost Horse Creek Canal transfers water into the Lick Creek basin from the Lost Horse Creek drainage to the north. When the canal is in use, water is diverted to irrigate pasture lands; minimal flows, if any, are directly discharged to Lick Creek. This trans-basin diversion may contribute flow and a nutrient load to the lowest stretches of Lick Creek through groundwater supplements or overland flow from flood irrigation.

Subsurface Wastewater Treatment and Disposal

According to DEQ information, there are 8 individual septic systems in the Lick Creek watershed. All of the individual septic systems are below the USFS boundary. Although most of the systems are away from the stream corridor, there are three within close proximity (<100 ft) to the stream. Septic effluent may be a minor contributor to the existing Lick Creek TP load.

Silviculture

An analysis of aerial imagery and geospatial land cover data shows parcels of land with recently harvested forest on both sides of the stream. According to geospatial information provided by the USFS, there have been some recent forest management/harvest activities in the past 10 years on several small parcels on both sides of the stream channel. Aerial images show a network of unpaved forestry roads in the watershed, which may contribute to sediment loading in the watershed. Based on the data presented in **Figure 5-32**, contributions of TP to Lick Creek from silviculture is not thought to be a substantial contributor to the TP load; however, there was a single exceedance at the most upstream sampling location on USFS administered land.

Mining

According to DEQ and MBMG databases, no historic mining has occurred in the Lick Creek watershed.

5.6.7.3 TP TMDL, Allocations, and Current Loading

The TMDL for TP is based on **Equation 5** and the TMDL allocations are based on **Equation 6.** The value of the TP TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. The following example TP TMDL for Lick Creek uses **Equation 5** with the median measured flow from all sites during 2004-2012 sampling (3.235 cfs):

$$\textbf{TMDL = (0.030 mg/L) (3.235 cfs) (5.4) = 0.524 lbs/day}$$

Equation 7 is the basis for the natural background load allocation for TP. To continue with the example at a flow of 3.235 cfs, this allocation is as follows:

$$LA_{NB} = (0.010 \text{ mg/L}) (3.235 \text{ cfs}) (5.4) = 0.175 \text{ lbs/day}$$

Using **Equation 8**, the human-caused TP load allocation at 3.235 cfs can be calculated:

$$LA_{H} = 0.524 \text{ lbs/day} – 0.175 \text{ lbs/day} = 0.349 \text{ lbs/day}$$

An example total existing load is based on **Equation 9**, and is calculated as follows using the median of TP target exceedance values measured from Lick Creek from 2004-2012 (0.037 mg/L) and the median measured flow of 3.235 cfs:

$$\text{Total Existing Load} = (0.037\text{mg/L}) (3.235 \text{ cfs}) (5.4) = 0.646 \text{ lbs/day}$$

The portion of the total existing load attributed to human sources is 0.472 lbs/day, which is determined by subtracting out the 0.175 lbs/day background load. This 0.472 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-38 contains the results for the example TP TMDL, LAs, and current loading. In addition, it contains an example percent reduction to the human-caused LA required to meet the water quality target for TP. At the median growing season flow of 3.235 cfs, and the median of measured TP target exceedance values, the current loading in Lick Creek is greater than the TMDL. Under these example conditions, a 26% reduction of human-caused TP loads, which results in an overall 19% reduction of TP in Lick Creek, would result in the TMDL being met. The source assessment of the Lick Creek watershed indicates that agriculture and silviculture are the most likely sources of TP in Lick Creek; load reductions should focus on limiting and controlling TP loading from these sources. Meeting LAs for Lick Creek may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 9.4.1**.

Table 5-38. Lick Creek TP Example TMDL, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction
Natural Background	0.175	0.175	0%
Human-caused (primarily agriculture and silviculture)	0.349	0.472	26%
	TMDL = 0.524	**Total = 0.647**	**Total = 19%**

[1]Based on a median growing season flow of 3.235 cfs

Figure 5-33 shows the percent reductions for TP loads measured in Lick Creek from 2004-2012. Because flow data were absent for some of the water quality samples, percent reductions were calculated for the sampling locations where the measured TP concentrations were above the target. Any time concentration exceeds the target, the corresponding load, even if flow is not measured, exceeds the TMDL since the TMDL equation is based on concentration multiplied by the flow. Loads greater than the

TMDL require reductions, so percent reductions in TP loads are the same as percent reductions in TP concentrations. For Lick Creek, there were multiple TP target exceedances from different sampling events at two of the sampling locations, so the TP reductions for all exceedances at those sites were calculated and plotted. Based on the results presented in **Figure 5-33**, TP load reductions ranging from 3% to 30%, with a median overall reduction of 19%, are necessary to meet the TMDL.

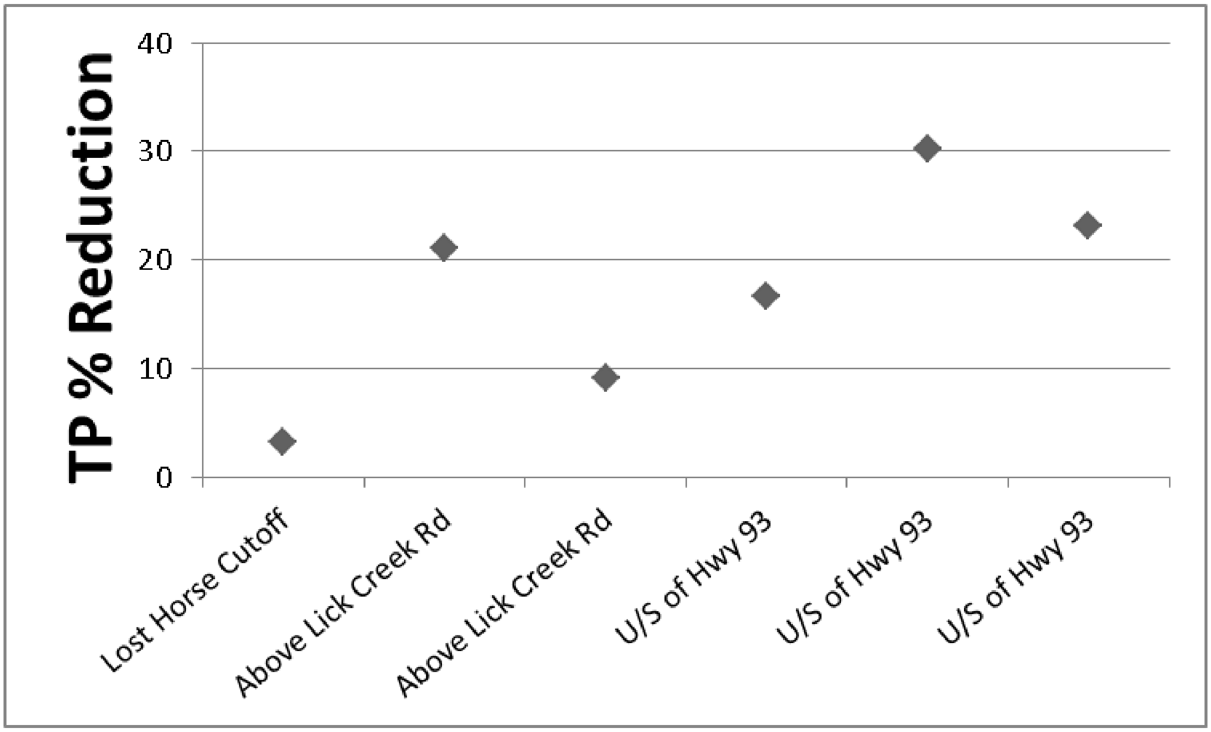


Figure 5-33. Measured TP Percent Load Reductions for Lick Creek (Each TP target exceedance for a site were plotted.)

5.6.8 North Fork Rye Creek

North Fork Rye Creek begins in the Sapphire Mountains on the east side of the Bitterroot Valley and flows 7.1 miles from the headwaters to its confluence with Rye Creek. The headwaters are predominately Bitterroot National Forest lands, while approximately the lower 1.3 miles border private lands.

5.6.8.1 Assessment of Water Quality Results

The source assessment for North Fork Rye Creek consists of an evaluation of TN and TP concentrations, followed by an estimation of the most significant human-caused sources of nutrients. **Figure 5-34** presents the approximate locations of data pertinent to the source assessment in the North Fork Rye Creek watershed.

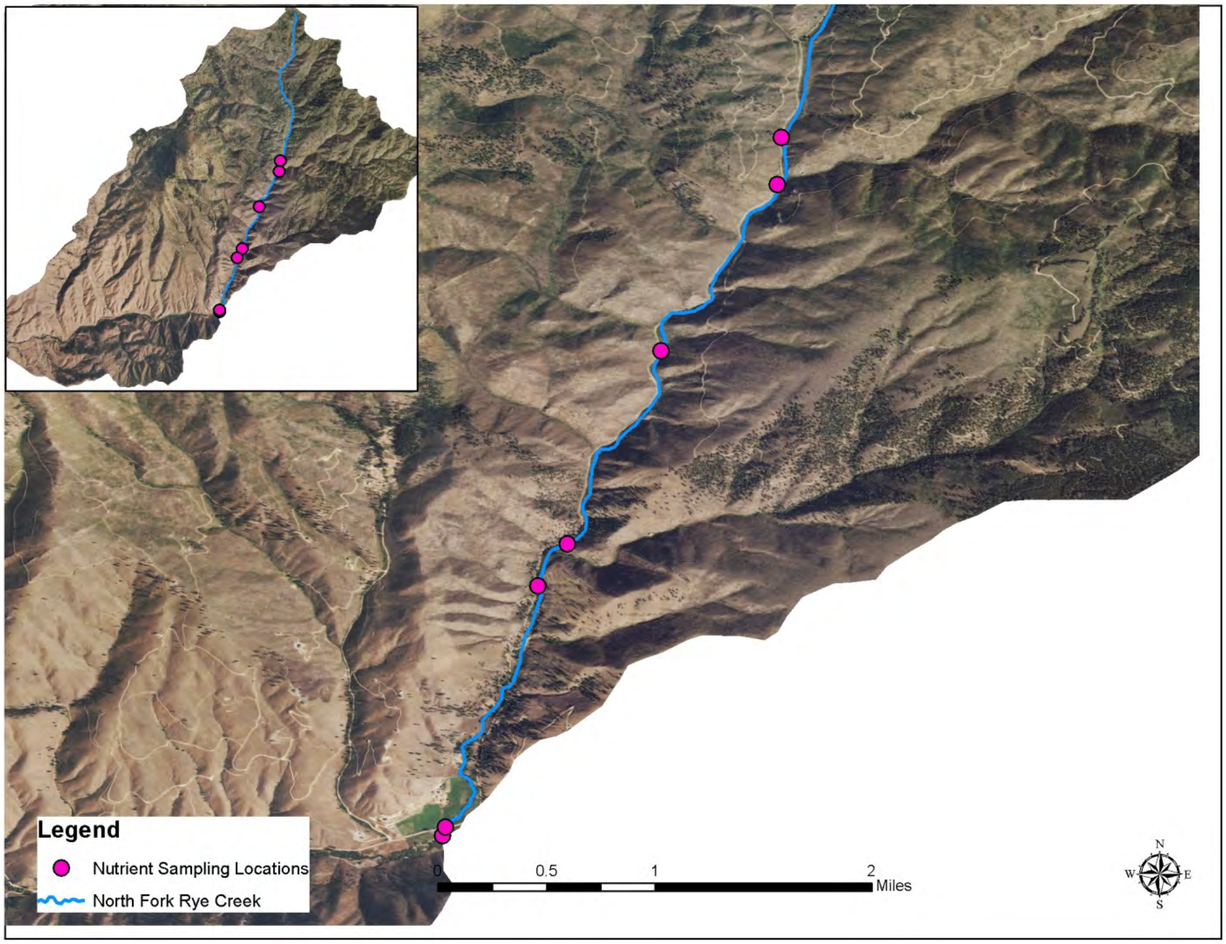


Figure 5-34. North Fork Rye Creek Watershed with Water Quality Sampling Locations

Total Nitrogen

DEQ collected water quality samples for TN from North Fork Rye Creek during the growing season between 2007 and 2012 (**Section 5.4.3.6, Table 5-13**). Out of 13 total samples, 3 exceeded the TN target of 0.275 mg/L. All of the TN exceedances for North Fork Rye Creek occur near the mouth. **Figure 5-35** presents summary statistics for TN concentrations at sampling sites in North Fork Rye Creek.

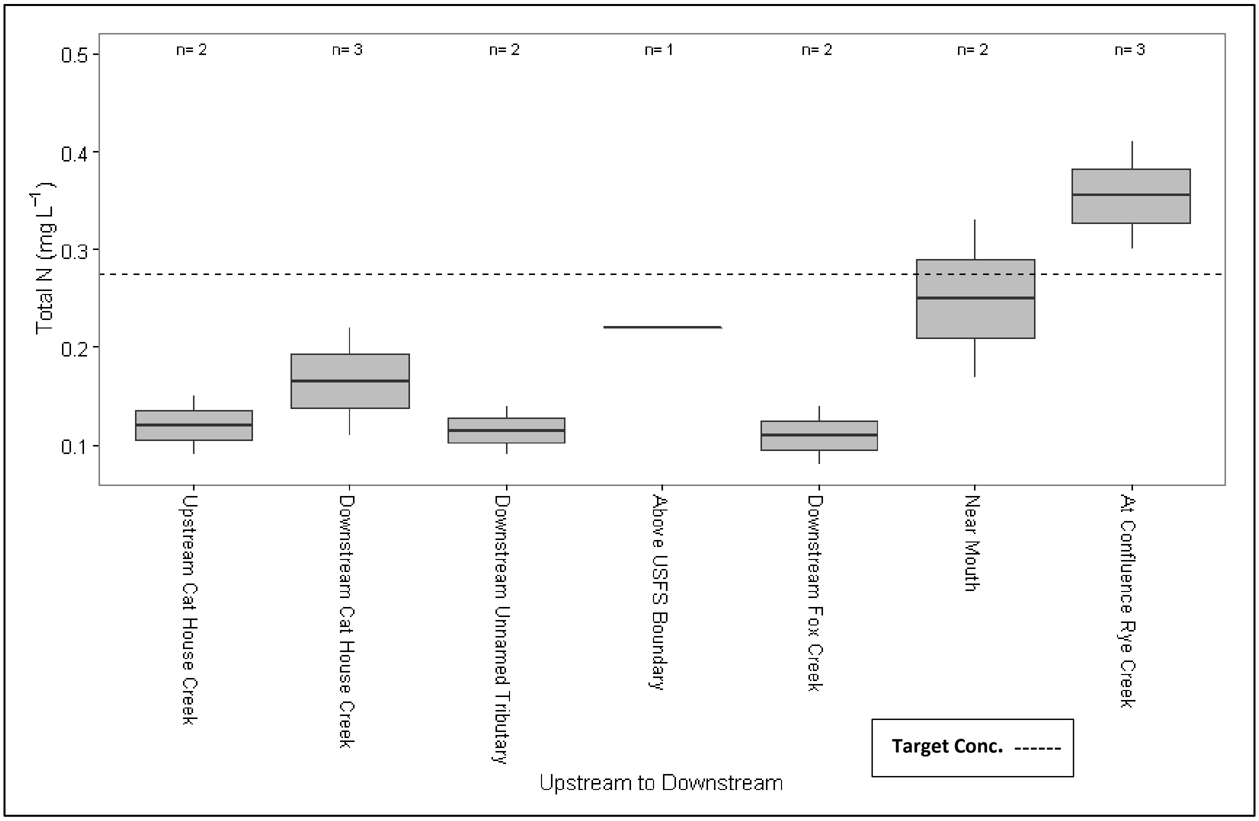


Figure 5-35. Boxplots of TN Concentrations in North Fork Rye Creek (2007-2012)

Total Phosphorus

DEQ collected water quality samples for TP from North Fork Rye Creek during the growing season between 2006 and 2012 (**Section 5.4.3.6, Table 5-13**). Out of 15 total samples, 5 exceeded the TP target of 0.025 mg/L. Although there was a single TP exceedance Upstream of Cat House Creek, which is in the forested upper reach of North Fork Rye Creek, most of the TP exceedances occurred near the mouth. In addition, there was one AFDM exceedance at the Downstream of Unnamed Tributary sampling location, which is in a steep drainage where the forested area was heavily burned. The TP concentration for the water quality sample collected on the same date at the same location was at the target of 0.025 mg/L. **Figure 5-36** presents summary statistics for TP concentrations at sampling sites in North Fork Rye Creek.

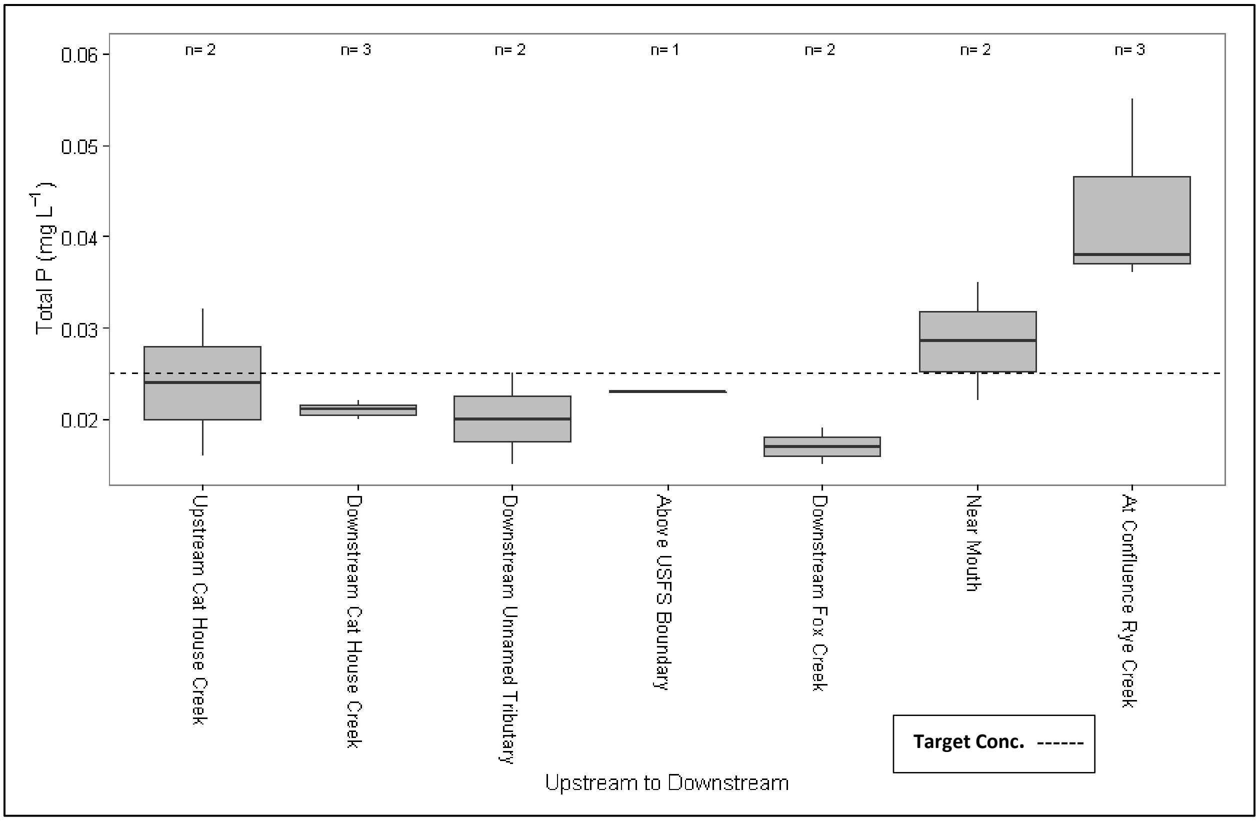


Figure 5-36. Boxplots of TP Concentrations in North Fork Rye Creek (2006-2012)

5.6.8.2 Source Assessment

The majority of the North Fork Rye Creek watershed drains recently burned forest land cover within the Bitterroot National Forest. In the summer of 2000, the North Fork Rye Creek watershed was burned extensively by wildfires. Over 21,000 acres burned in the Upper and Lower Rye Creek watersheds during the 2000 fire. There is still evidence of wildfire along North Fork Rye Creek. While the majority of the watershed is forested, some grassland and small properties with hay or pasture exist on privately owned land immediately downstream of the USFS Boundary.

Potential human sources that could contribute TP and TN to North Fork Rye Creek are agriculture (irrigated crops and grazing/pasture), silvicultural activities, and septic; based on the pulses of TN and TP near the mouth, the most likely significant nutrient sources in North Fork Rye Creek are agriculture and septic. Each of the potential human sources is discussed below, followed by an analysis of the sources.

Agriculture

Near the mouth of North Fork Rye Creek there are some irrigated hay/alfalfa fields and several small livestock confinement areas and horse grazing areas along the channel. There are no active grazing permits on the USFS administered portion of the watershed, so the only agricultural influence from crops and livestock is on private lands in the lowermost section of North Fork Rye Creek.

From geospatial database information, there are two small irrigation withdrawals from North Fork Rye Creek on the lower reach. Within the watershed and including livestock sources, irrigation return flows from overland runoff and groundwater recharge in the lower watershed may be likely flow pathways by which nutrients are reaching North Fork Rye Creek.

Subsurface Wastewater Treatment and Disposal
According to DEQ information, there are 19 individual septic systems in the North Fork Rye Creek watershed. All of the individual septic systems are concentrated in the 1.3 miles from the mouth of the stream. There are several systems within close proximity (<100 ft) to the stream. Based on the spike in both TP and TN concentrations near the mouth, septic effluent is a likely contributor to the existing North Fork Rye Creek TN and TP loads.

Silviculture
A majority of the watershed is on forested lands that were burned extensively by the 2000 wildfires. It is recognized that the 2000 fires are still having an effect on the watershed, and the natural background of phosphorus in the watershed may be underestimated, since the natural background value that was based on median concentration values from reference sites in the Idaho Batholith ecoregion represents ideal conditions without an input from an unexpected nutrient pulse from a fire. However, there are human activities in the lower reach of the stream that are more likely contributing to the excess TN and TP loads.

An analysis of aerial imagery and geospatial land cover data shows parcels of land with recently harvested forest on both sides of the stream. According to geospatial information provided by the USFS, there have been some recent forest management/harvest activities in the past 10 years on several small parcels on both sides of the stream channel, with some activities very close to the stream channel.

Aerial images of the watershed show an extensive network of unpaved forestry roads, which may contribute to sediment loading in the watershed. North Fork Rye Creek Road is along much of the stream channel and is in close proximity for a lot of the reach. Some riparian buffer exists between the road and the channel in some places; however, in a number of locations where the road is in very close proximity to the stream, there does not appear to be an adequate riparian buffer.

There was a single target exceedance for TP upstream of Cat House Creek in the forested area. Runoff from the fires, timber harvest activity, and logging roads within close proximity to the stream channel are likely contributing phosphorus to the segment and may explain the TP exceedance in the forested area.

Mining
According to DEQ and MBMG databases, no historic mining has occurred in the North Fork Rye Creek watershed.

5.6.8.3 TN TMDL, Allocations, and Current Loading
The TMDL for TN is based on **Equation 5** and the TMDL allocations are based on **Equation 6.** The value of the TN TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. The following example TN TMDL for North Fork Rye Creek uses **Equation 5** with the median measured flow from all sites during 2007-2012 sampling (0.41 cfs):

TMDL = (0.275 mg/L) (0.41 cfs) (5.4) = 0.609 lbs/day

Equation 7 is the basis for the natural background load allocation for TN. To continue with the example at a flow of 0.41 cfs, this allocation is as follows:

$$\mathbf{LA_{NB} = (0.070\ mg/L)\ (0.41\ cfs)\ (5.4) = 0.155\ lbs/day}$$

Using **Equation 8**, the human-caused TN load allocation at 0.41 cfs can be calculated:

$$\mathbf{LA_{H} = 0.609\ lbs/day – 0.155\ lbs/day = 0.454\ lbs/day}$$

An example total existing load is based on **Equation 9**, and is calculated as follows using the median of TN target exceedance values measured from North Fork Rye Creek from 2007-2012 (0.33 mg/L) and the median measured flow of 0.41 cfs:

Total Existing Load = (0.33 mg/L) (0.41 cfs) (5.4) = 0.731 lbs/day

The portion of the total existing load attributed to human sources is 0.576 lbs/day, which is determined by subtracting out the 0.155 lbs/day background load. This 0.576 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-39 contains the results for the example TN TMDL, LAs, and current loading. In addition, it contains an example percent reduction to the human-caused LA required to meet the water quality target for TN. At the median growing season flow of 0.41 cfs, and the median of measured TN target exceedance values, the current loading in North Fork Rye Creek is greater than the TMDL. Under these example conditions, a 21% reduction of human-caused TN loads, which results in an overall 17% reduction of TN in North Fork Rye Creek, would result in the TMDL being met. The source assessment of the North Fork Rye Creek watershed indicates that septic, grazing in the riparian zone, and crop production are the most likely sources of TN in North Fork Rye Creek; load reductions should focus on limiting and controlling TN loading from these sources. Meeting LAs for North Fork Rye Creek may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 9.4.1**.

Table 5-39. North Fork Rye Creek TN Example TMDL, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction
Natural Background	0.155	0.155	0%
Human-caused (agriculture and septic)	0.454	0.576	21%
	TMDL = 0.609	**Total = 0.731**	**Total = 17%**

[1]Based on a median growing season flow of 0.41 cfs

Figure 5-37 shows the percent reductions for TN loads measured in North Fork Rye Creek from 2007-2012. Because flow data were absent for some of the water quality samples, percent reductions were calculated for the sampling locations where the measured TN concentrations were above the target. Any time concentration exceeds the target, the corresponding load, even if flow is not measured, exceeds the TMDL since the TMDL equation is based on concentration multiplied by the flow. Loads greater than the TMDL require reductions, so percent reductions in TN loads are the same as percent reductions in TN concentrations. For North Fork Rye Creek, there were two TN target exceedances from different sampling events at the Rye Creek Confluence sampling location, so both TN reductions were calculated and plotted for that site. Based on the results presented in **Figure 5-37**, TN load reductions ranging from 8% to 33%, with a median overall reduction of 17%, are necessary to meet the TMDL.

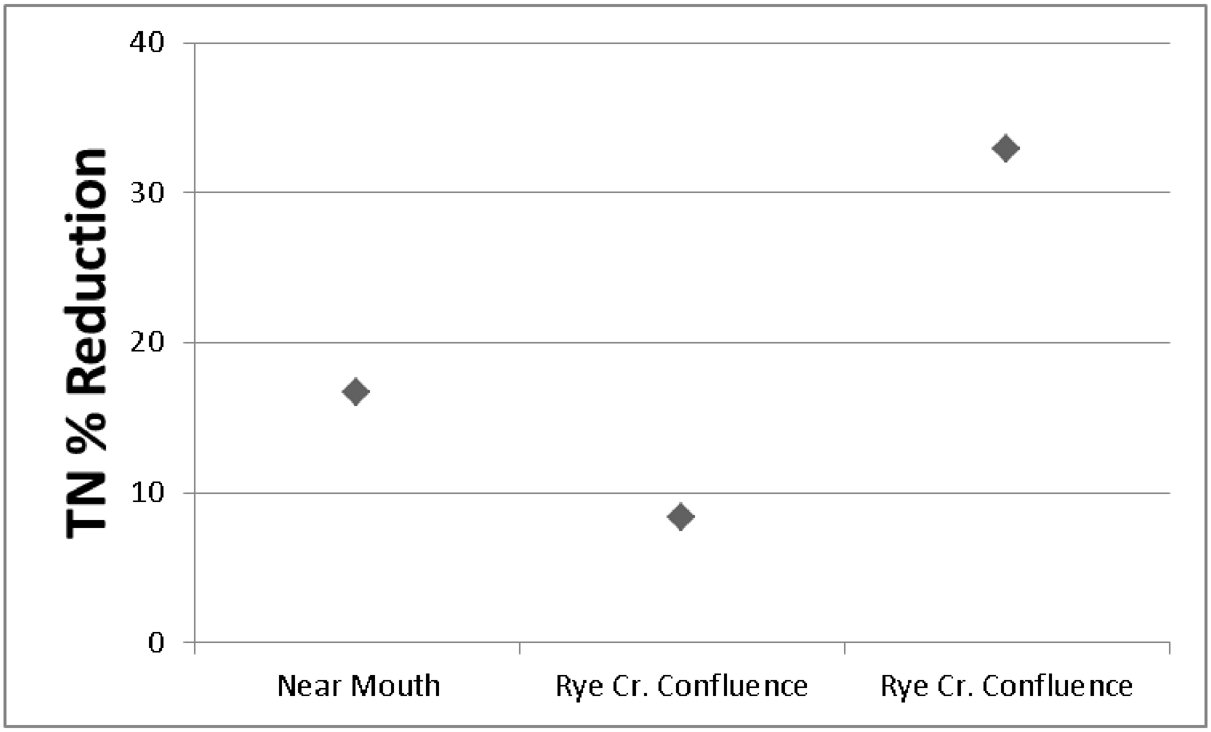


Figure 5-37. Measured TN Percent Load Reductions for North Fork Rye Creek (Each TN target exceedance for a site were plotted.)

5.6.8.4 TP TMDL, Allocations, and Current Loading

The TMDL for TP is based on **Equation 5** and the TMDL allocations are based on **Equation 6.** The value of the TP TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. The following example TP TMDL for North Fork Rye Creek uses **Equation 5** with the median measured flow from all sites during 2006-2012 sampling (0.41 cfs):

TMDL = (0.025 mg/L) (0.41 cfs) (5.4) = 0.055 lbs/day

Equation 7 is the basis for the natural background load allocation for TP. To continue with the example at a flow of 0.41 cfs, this allocation is as follows:

LA_{NB} = (0.006 mg/L) (0.41 cfs) (5.4) = 0.013 lbs/day

Using **Equation 8**, the human-caused TP load allocation at 0.41 cfs can be calculated:

LA_{H} = 0.055 lbs/day – 0.013 lbs/day = 0.042 lbs/day

An example total existing load is based on **Equation 9**, and is calculated as follows using the median of TP target exceedance values measured from North Fork Rye Creek from 2006-2012 (0.036 mg/L) and the median measured flow of 0.41 cfs:

Total Existing Load = (0.036 mg/L) (0.41 cfs) (5.4) = 0.080 lbs/day

The portion of the total existing load attributed to human sources is 0.066 lbs/day, which is determined by subtracting out the 0.013 lbs/day background load. This 0.066 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-40 contains the results for the example TP TMDL, LAs, and current loading. In addition, it contains an example percent reduction to the human-caused LA required to meet the water quality target for TP. At the median growing season flow of 0.41cfs, and the median of measured TP target exceedance values, the current loading in North Fork Rye Creek is greater than the TMDL. Under these example conditions, a 37% reduction of human-caused TP loads, which results in an overall 31% reduction of TP in North Fork Rye Creek, would result in the TMDL being met. The source assessment of the North Fork Rye Creek watershed indicates that silviculture activities and forest roads, septic, grazing in the riparian zone, and crop production are the most likely sources of TP in North Fork Rye Creek; load reductions should focus on limiting and controlling TP loading from these sources. Meeting LAs for North Fork Rye Creek may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 9.4.1**.

Table 5-40. North Fork Rye Creek TP Example TMDL, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction
Natural Background	0.013	0.013	0%
Human-caused (silviculture, agriculture, septic)	0.042	0.066	37%
	TMDL = 0.055	**Total = 0.080**	**Total = 31%**

[1]Based on a median growing season flow of 0.41 cfs

Figure 5-38 shows the percent reductions for TP loads measured in North Fork Rye Creek from 2007-2012. Because flow data were absent for some of the water quality samples, percent reductions were calculated for the sampling locations where the measured TP concentrations were above the target. Any time concentration exceeds the target, the corresponding load, even if flow is not measured, exceeds the TMDL since the TMDL equation is based on concentration multiplied by the flow. Loads greater than the TMDL require reductions, so percent reductions in TP loads are the same as percent reductions in TP concentrations. For North Fork Rye Creek, there were multiple TP target exceedances from different sampling events at the Rye Creek Confluence sampling location, so the TP reductions for all exceedances at that site were calculated and plotted. Based on the results presented in **Figure 5-38**, TP load reductions ranging from 22% to 56%, with a median overall reduction of 31%, are necessary to meet the TMDL.

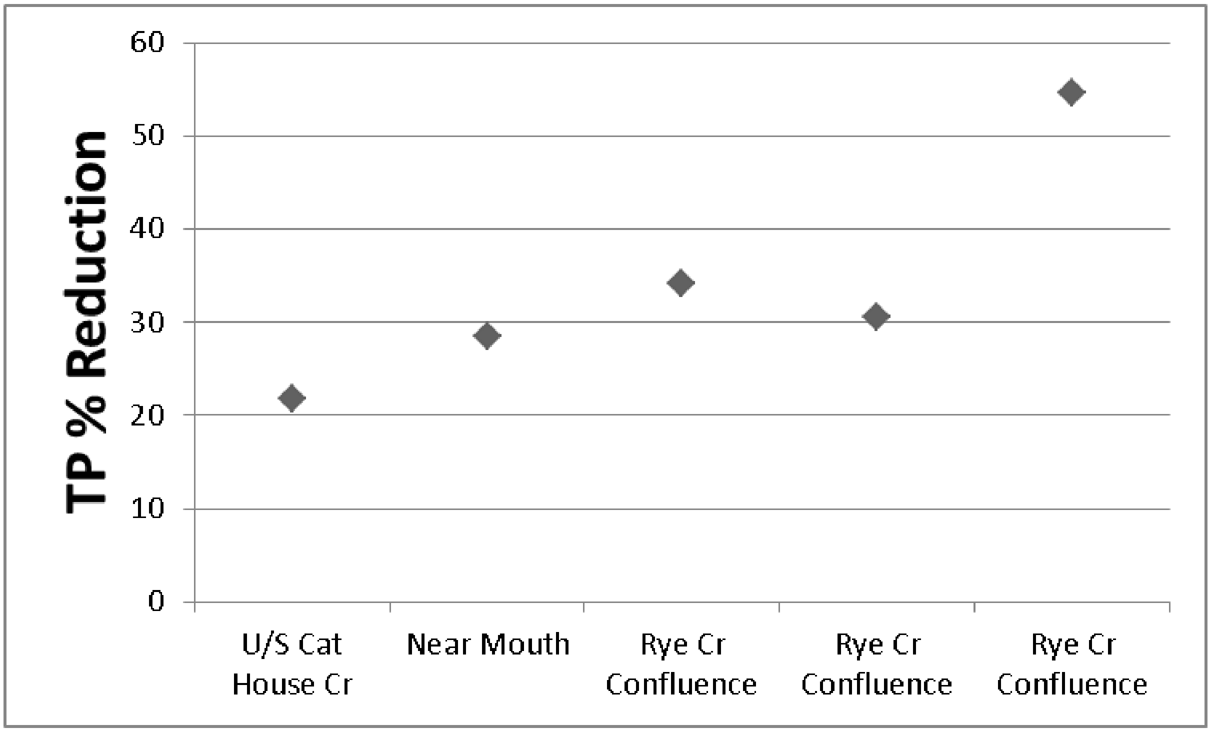


Figure 5-38. Measured TP Percent Load Reductions for North Fork Rye Creek (Each TP target exceedance for a site were plotted.)

5.6.9 Rye Creek

Rye Creek begins in the Sapphire Mountains on the east side of the Bitterroot Valley and flows for 17.5 miles before reaching its confluence with the Bitterroot River. The stream's headwaters are predominately Bitterroot National Forest lands, while approximately the lower 6 miles are bordered by private lands.

5.6.9.1 Assessment of Water Quality Results

The source assessment for Rye Creek consists of an evaluation of TN and TP concentrations, followed by an estimation of the most significant human-caused sources of nutrients. **Figure 5-39** presents the approximate locations of data pertinent to the source assessment in the Upper and Lower Rye Creek watersheds.

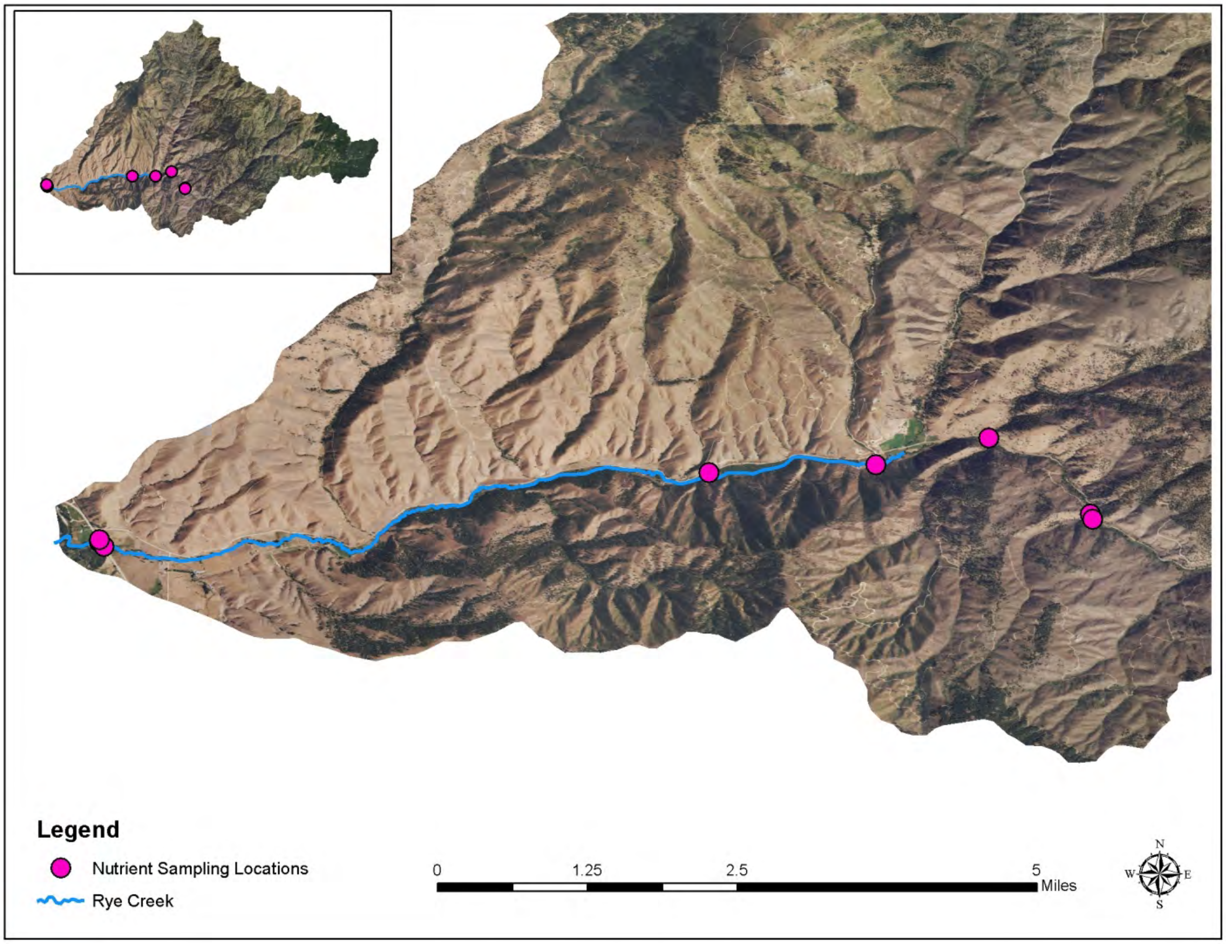


Figure 5-39. Upper and Lower Rye Creek watersheds with water quality sampling locations

Total Nitrogen

DEQ collected water quality samples for TN from Rye Creek during the growing season between 2007 and 2012 (**Section 5.4.3.7, Table 5-15**). Out of eight total samples, two exceeded the TN target of 0.275 mg/L. The two TN exceedances for Rye Creek both occurred near the mouth, downstream of the agricultural influence. Although there were TN concentration exceedances within North Fork Rye Creek at the confluence with Rye Creek, there were no TN target exceedances at the sampling location downstream of the confluence. **Figure 5-40** presents summary statistics for TN concentrations at sampling sites in Rye Creek.

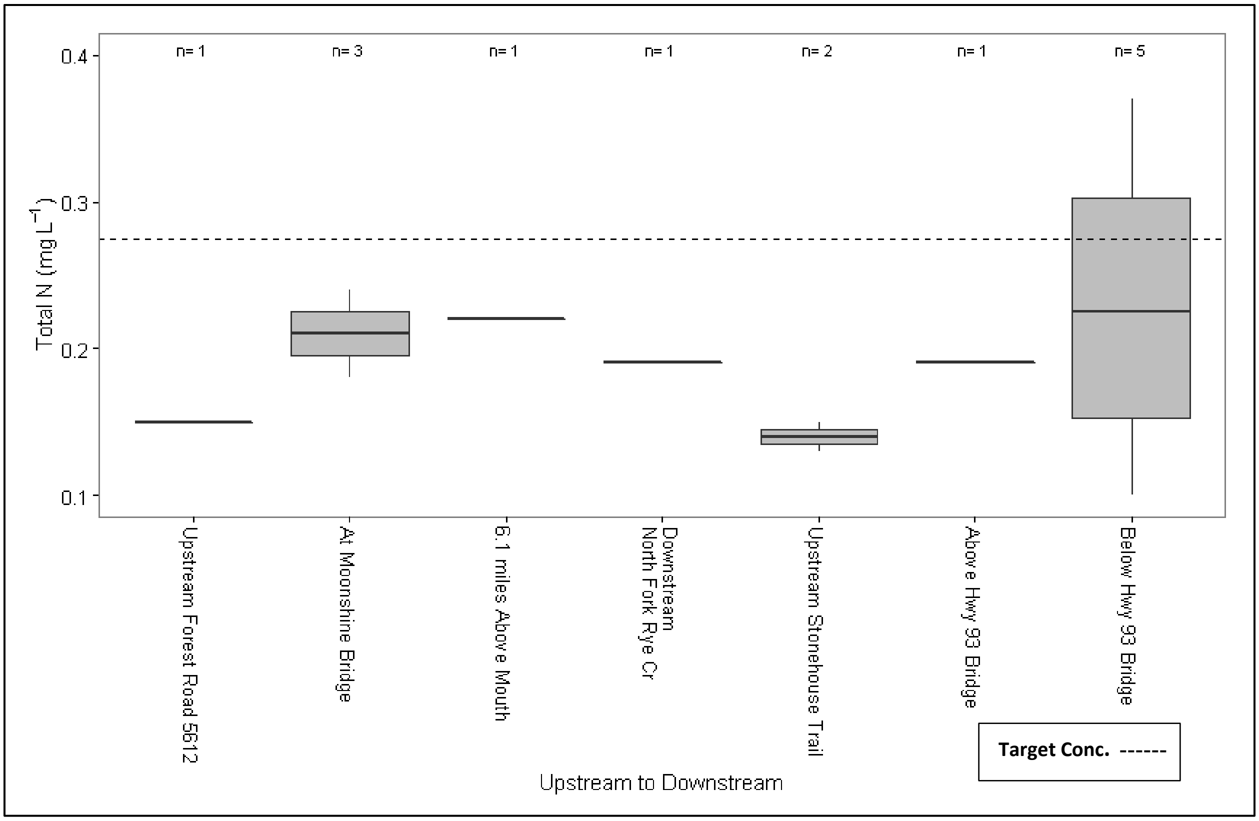


Figure 5-40. Boxplots of TN Concentrations in Rye Creek (2007-2012)

Total Phosphorus

DEQ collected water quality samples for TP from Rye Creek during the growing season between 2006 and 2012 (**Section 5.4.3.7, Table 5-15**). Out of nine total samples, four exceeded the TP target of 0.025 mg/L. The TP exceedances occurred throughout the reach with the highest magnitude of exceedances occurring at Moonshine Bridge. At the Moonshine Bridge sampling location, Moonshine Connection Road converges with Rye Creek Road in a steep drainage where the forested areas were heavily burned. The median concentration of TP at the confluence with North Fork Rye Creek was 0.038 mg/L and there was a TP target exceedance at the sampling location downstream of North Fork Rye Creek. **Figure 5-41** presents summary statistics for TP concentrations at sampling sites in Rye Creek.

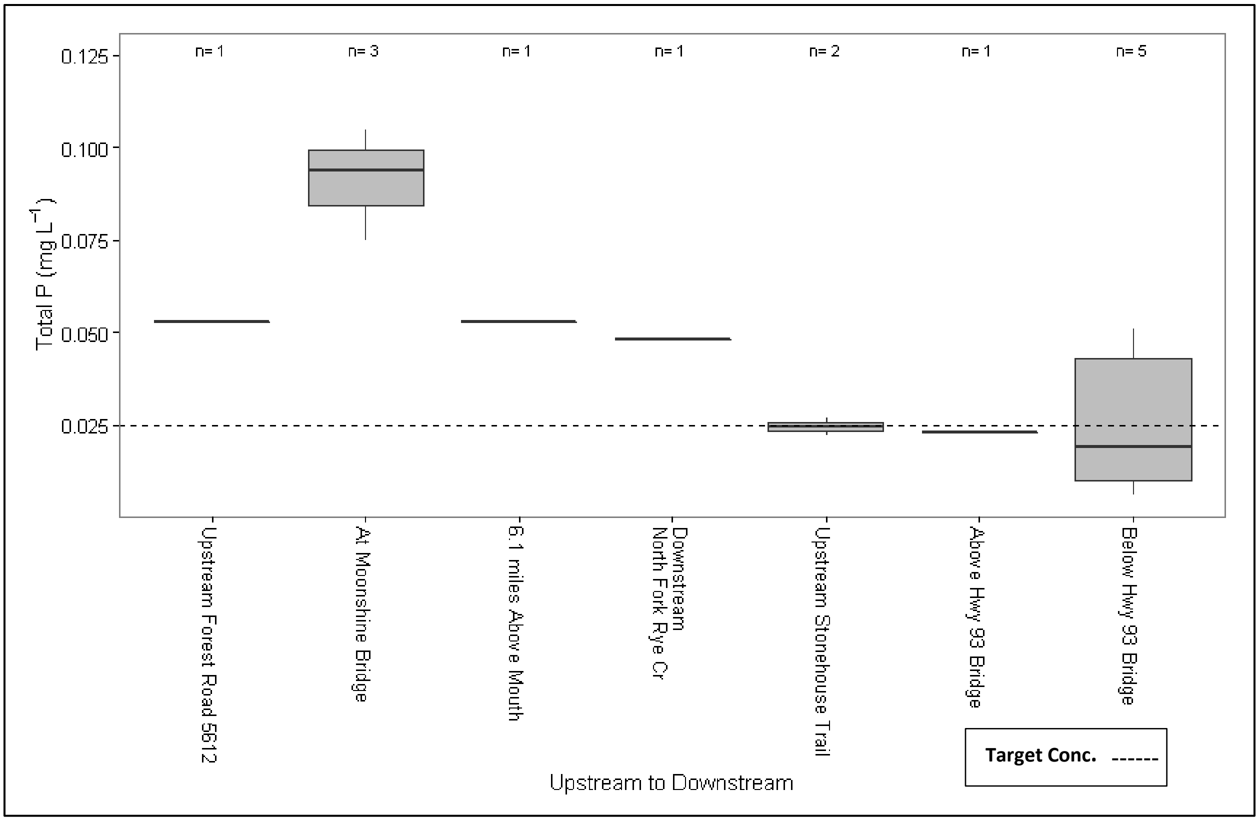


Figure 5-41. Boxplots of TP Concentrations in Rye Creek (2006-2012)

5.6.9.2 Source Assessment

The majority of the Rye Creek watershed (Upper and Lower) drains recently burned forest land cover within the Bitterroot National Forest. In the summer of 2000, the headwaters of the Rye Creek watershed were burned extensively by wildfires. Over 21,000 acres burned in the Upper and Lower Rye Creek watersheds during the 2000 fire and there is still evidence of wildfire along the creek. While the majority of the watershed is forested, grassland and recently burned grassland as well as small properties with hay or pasture, exist on privately owned land downstream of the North Fork Rye Creek confluence.

A sediment TMDL for Rye Creek was completed in 2011 (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011a). As part of sediment TMDL development, DEQ performed stream assessments in 2007 along Rye Creek and it was noted that there was evidence of skid logging along the hillslope along river left which was burned during the 2000 fires. The forested land also contains a network of unpaved forestry roads that may contribute to sediment loading in the watershed. From the 2011 Bitterroot Sediment TMDL, streambank areas rated as poor condition were primarily in areas dominated by pastures, timber harvest/fire, and roads. In the lower reach of Rye Creek, a short distance upstream from Highway 93, it was noted from recent observations that there is very little riparian near the mouth and the stream appears to be channelized. There was road wash-out with signs of road runoff and sandy sediment was observed in the stream bottom.

Potential human sources that could contribute TP and TN to Rye Creek are silvicultural activities, forest roads, agriculture (irrigated crops, grazing in riparian or streamside zones, livestock confinement areas), and septic. Each of the potential human sources is discussed below, followed by an analysis of the sources.

Agriculture

In the lower reach of Rye Creek, near the confluence of North Fork Rye Creek and below Lowman Creek Road, is pasture grazing with some irrigated hay/alfalfa production and limited cultivated row crops along the channel. Recent field observations indicate evidence of cattle grazing along the riparian corridor, and old livestock corrals were present, although no permitted concentrated animal feeding operations exist in the area.

The Medicine Tree grazing allotment comprises 13,973 acres of USFS administered lands contained in several watersheds, including the Lower Rye Creek watershed, with an average number of 200 permitted AUMs on the allotment (**Table 5-24**) in any given year. The allotment encompasses 1,317 acres in the Lower Rye Creek watershed and is located in the forested areas of the southern portion of the watershed. Based on water quality data, the grazing allotments do not appear to be a significant source of nutrients, and the major agricultural influence is livestock grazing and crops on private lands in the lowermost section of Rye Creek.

From geospatial database information, there appear to be five small irrigation withdrawals from Rye Creek on the lower reach in the irrigated agricultural area. Within the watershed and including livestock sources, irrigation return flows from overland runoff and groundwater recharge in the lower drainage may be likely flow pathways by which nutrients are reaching Rye Creek.

Subsurface Wastewater Treatment and Disposal

According to DEQ information, there are 24 individual septic systems in the lower Rye Creek watershed. All of the individual septic systems are below the confluence with North Fork Rye Creek and beyond any influence from North Fork Rye Creek. Although most of the systems are away from the stream corridor, there are a relative few within close proximity (<100 ft) to the stream. Septic effluent may be a minor contributor to the existing Rye Creek TN and TP loads.

Silviculture

A majority of the watershed is on forested lands that were burned extensively by the 2000 wildfires. Although the impaired segment of Rye Creek is contained in the Lower Rye Creek Watershed, data from the Upper Rye Creek Watershed indicate that TP target exceedances occurred on Rye Creek above its confluence with North Fork Rye Creek. It is recognized that the 2000 fires are still having an effect on the watershed, and the natural background of phosphorus in the watershed may be underestimated, since the natural background value that was based on median concentration values from reference sites in the Idaho Batholith ecoregion represents ideal conditions without an input from an unexpected nutrient pulse from a fire. However, there are human activities present that are increasing erosion.

An analysis of aerial imagery and geospatial land cover data shows parcels of land with recently harvested forest on both sides of the stream. According to geospatial information provided by the USFS, there have been some recent forest management/harvest activities in the past 10 years on several small parcels on both sides of the stream channel, particularly in the upper segment of Rye Creek. Some activities occurred within close proximity to the stream channel.

Aerial images of the watershed show an extensive network of unpaved forestry roads, which may contribute to sediment loading in the watershed. Rye Creek Road is along much of the stream channel and is in close proximity in some places. A substantial riparian buffer exists between the road and the channel in most places; however, in a limited number of locations where the road is in very close proximity to the stream, there does not appear to be an adequate riparian buffer. Recent observations noted some road wash out and signs of road runoff on Rye Creek Road.

Runoff from the fires, timber harvest activity, and forestry roads within close proximity to the stream channel are likely contributing phosphorus to the segment and may explain the TP exceedances in the forested area.

Mining

According to DEQ and MBMG databases, there are several abandoned mines listed in the Rye Creek watershed. A thorium, titanium and uranium placer mine is located downstream of the confluence of Benson Creek along Rye Creek. Further upstream, off of Stonehouse Trail, is a tantalum mica lode prospect. Located in the uppermost part of the Upper Rye Creek watershed, there are two abandoned fluorine mines that do not appear to be having a discernible effect on instream water quality given their distance from the stream.

5.6.9.3 TN TMDL, Allocations, and Current Loading

The TMDL for TN is based on **Equation 5** and the TMDL allocations are based on **Equation 6.** The value of the TN TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. The following example TN TMDL for Rye Creek uses **Equation 5** with the median measured flow from all sites during 2007-2012 sampling (1.85 cfs):

TMDL = (0.275 mg/L) (1.85 cfs) (5.4) = 2.75 lbs/day

Equation 7 is the basis for the natural background load allocation for TN. To continue with the example at a flow of 1.85 cfs, this allocation is as follows:

LA_{NB} = (0.070 mg/L) (1.85 cfs) (5.4) = 0.699 lbs/day

Using **Equation 8**, the human-caused TN load allocation at 1.85 cfs can be calculated:

LA_{H} = 2.75 lbs/day – 0.699 lbs/day = 2.05 lbs/day

An example total existing load is based on **Equation 9**, and is calculated as follows using the median of TN target exceedance values measured from Rye Creek from 2007-2012 (0.325 mg/L) and the median measured flow of 1.85 cfs:

Total Existing Load = (0.325 mg/L) (0.41 cfs) (5.4) = 3.25 lbs/day

The portion of the total existing load attributed to human sources is 2.55 lbs/day, which is determined by subtracting out the 0.699 lbs/day background load. This 2.55 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-41 contains the results for the example TN TMDL, LAs, and current loading. In addition, it contains an example percent reduction to the human-caused LA required to meet the water quality target for TN. At the median growing season flow of 1.85 cfs, and the median of measured TN target exceedance values, the current loading in Rye Creek is greater than the TMDL. Under these example conditions, a 20% reduction of human-caused TN loads, which results in an overall 15% reduction of TN in Rye Creek, would result in the TMDL being met. The source assessment of the Rye Creek watershed indicates that sedimentation from silviculture activities and forest roads, septic, grazing in the riparian zone, and crop production are the most likely sources of TN in Rye Creek; load reductions should focus on limiting and controlling TN loading from these sources. Meeting LAs for Rye Creek may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 9.4.1**.

Table 5-41. Rye Creek TN Example TMDL, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction
Natural Background	0.699	0.699	0%
Human-caused (silviculture, septic, agriculture)	2.05	2.55	20%
	TMDL = 2.75	**Total = 3.25**	**Total = 15%**

[1]Based on a median growing season flow of 1.85 cfs

Figure 5-42 shows the percent reductions for TN loads measured in Rye Creek from 2007-2012. Because flow data were absent for some of the water quality samples, percent reductions were calculated for the sampling locations where the measured TN concentrations were above the target. Any time concentration exceeds the target, the corresponding load, even if flow is not measured, exceeds the TMDL since the TMDL equation is based on concentration multiplied by the flow. Loads greater than the TMDL require reductions, so percent reductions in TN loads are the same as percent reductions in TN concentrations. For Rye Creek, there were two TN target exceedances from different sampling events at the Below Hwy 93 Bridge sampling location, so both TN reductions were calculated and plotted for that site. Based on the results presented in **Figure 5-42**, TN load reductions ranging from 2% to 26%, with a median overall reduction of 14%, are necessary to meet the TMDL.

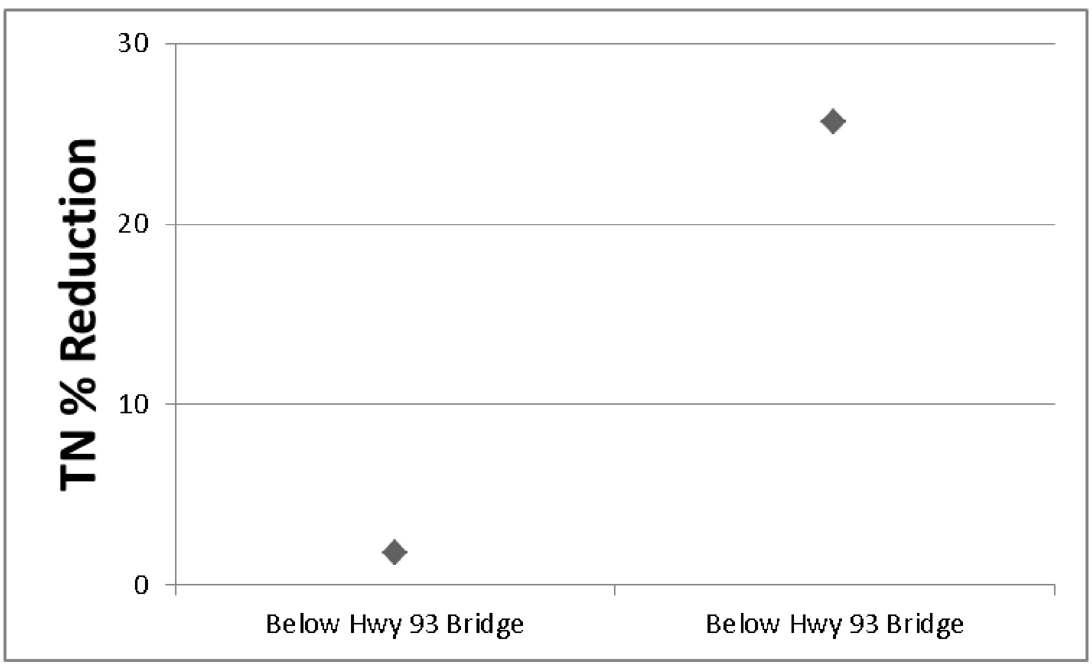


Figure 5-42. Measured TN Percent Load Reductions for Rye Creek (Each TN target exceedance for a site were plotted.)

5.6.9.4 TP TMDL, Allocations, and Current Loading

The TMDL for TP is based on **Equation 5** and the TMDL allocations are based on **Equation 6.** The value of the TP TMDL is a function of the flow; an increase in flow results in an increase in the TMDL. The following example TP TMDL for Rye Creek uses **Equation 5** with the median measured flow from all sites during 2006-2012 sampling (1.85 cfs):

TMDL = (0.025 mg/L) (1.85 cfs) (5.4) = 0.250 lbs/day

Equation 7 is the basis for the natural background load allocation for TP. To continue with the example at a flow of 1.85 cfs, this allocation is as follows:

LA_{NB} = (0.006 mg/L) (1.85 cfs) (5.4) = 0.060 lbs/day

Using **Equation 8**, the human-caused TP load allocation at 0.41 cfs can be calculated:

LA_{H} = 0.250 lbs/day – 0.060 lbs/day = 0.190 lbs/day

An example total existing load is based on **Equation 9**, and is calculated as follows using the median of TP target exceedance values measured from Rye Creek from 2006-2012 (0.053 mg/L) and the median measured flow of 1.85 cfs:

Total Existing Load = (0.053 mg/L) (1.85 cfs) (5.4) = 0.529 lbs/day

The portion of the total existing load attributed to human sources is 0.470 lbs/day, which is determined by subtracting out the 0.060 lbs/day background load. This 0.470 lbs/day value represents the load measured within the stream after potential nutrient uptake.

Table 5-42 contains the results for the example TP TMDL, LAs, and current loading. In addition, it contains an example percent reduction to the human-caused LA required to meet the water quality target for TP. At the median growing season flow of 1.85 cfs, and the median of measured TP target exceedance values, the current loading in Rye Creek is greater than the TMDL. Under these example conditions, a 60% reduction of human-caused TP loads, which results in an overall 53% reduction of TP in Rye Creek, would result in the TMDL being met. The source assessment of the Rye Creek watershed indicates that sedimentation from silviculture activities and forest roads, septic, grazing in the riparian zone, and crop production are the most likely sources of TP in Rye Creek; load reductions should focus on limiting and controlling TP loading from these sources. Meeting LAs for Rye Creek may be achieved through a variety of water quality planning and implementation actions and is addressed in **Section 9.4.1**.

Table 5-42. Rye Creek TP Example TMDL, LAs, Current Loading, and Reductions

Source Category	Allocation and TMDL (lbs/day)[1]	Existing Load (lbs/day)[1]	Percent Reduction
Natural Background	0.060	0.060	0%
Human-caused (silviculture, septic, agriculture)	0.190	0.470	60%
	TMDL = 0.250	**Total = 0.529**	**Total = 53%**

[1]Based on a median growing season flow of 1.85 cfs

Figure 5-43 shows the percent reductions for TP loads measured in Rye Creek from 2006-2012. Because flow data were absent for some of the water quality samples, percent reductions were calculated for the sampling locations where the measured TP concentrations were above the target. Any time concentration exceeds the target, the corresponding load, even if flow is not measured, exceeds the TMDL since the TMDL equation is based on concentration multiplied by the flow. Loads greater than the TMDL require reductions, so percent reductions in TP loads are the same as percent reductions in TP concentrations. For Rye Creek, there were multiple TP target exceedances from different sampling events at the Moonshine Bridge and Below Hwy 93 Bridge sampling locations, so the TP reductions for all exceedances at those sites were calculated and plotted. Based on the results presented in **Figure 5-43**, TP load reductions ranging from 7% to 76%, with a median overall reduction of 53%, are necessary to meet the TMDL.

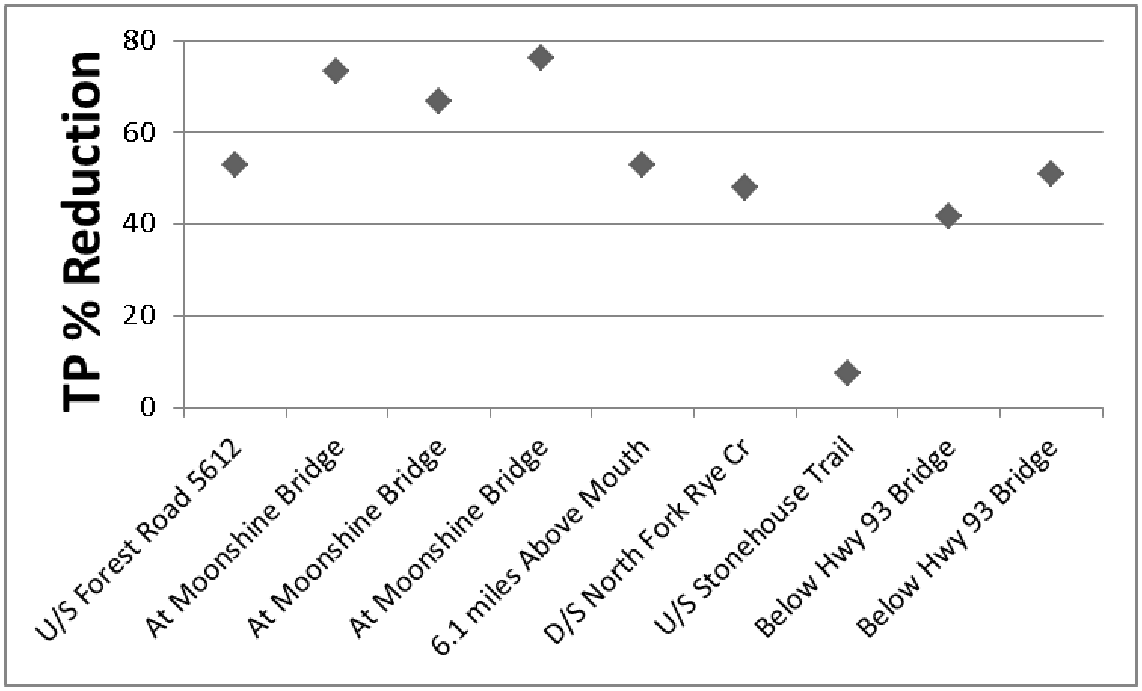


Figure 5-43. Measured TP Percent Load Reductions for Rye Creek (Each TP target exceedance for a site were plotted.)

5.7 Seasonality and Margin of Safety

TMDL documents must consider the seasonal variability, or seasonality, on water quality impairment conditions, maximum allowable pollutant loads in a stream (TMDLs), and Load Allocations (LAs). TMDL development must also incorporate a margin of safety (MOS) to account for uncertainties between pollutant sources and the quality of the receiving waterbody, and to ensure (to the degree practicable) that the TMDL components and requirements are sufficiently protective of water quality and beneficial uses. This section describes seasonality and MOS in the Bitterroot project area nutrient TMDL development process.

5.7.1 Seasonality

Addressing seasonal variations is an important and required component of TMDL development and throughout this plan, seasonality is an integral consideration. Water quality and particularly nitrogen concentrations are recognized to have seasonal cycles. Specific examples of how seasonality has been addressed within this document include:

- Water quality targets and subsequent allocations are applicable for the summer growing season (July 1 to September 30), to coincide with seasonal algal growth targets.
- Nutrient data used to determine compliance with targets and to establish allowable loads were collected during the summertime period to coincide with applicable nutrient targets.
- Flow values used in calculating example nutrient TMDLs contained in **Section 5.6** were collected during the summer growing season (July 1 to September 30) and are considered representative of low flow conditions during which nutrient concentration and seasonal algal growth targets apply.

5.7.2 Margin of Safety

A margin of safety (MOS) is a required component of TMDL development. The MOS accounts for the uncertainty about the pollutant loads and the quality of the receiving water and is intended to protect beneficial uses in the face of this uncertainty. The MOS may be applied implicitly by using conservative assumptions in the TMDL development process or explicitly by setting aside a portion of the allowable loading (U.S. Environmental Protection Agency, 1999). This plan addresses MOS implicitly in a variety of ways:

- Static nutrient target values (0.030 mg/L TP, 0.300 mg/L TN and 0.10 mg/L NO_3+NO_2 for Middle Rockies; 0.025 mg/L TP, 0.275 mg/L TN and 0.10 mg/L NO_3+NO_2 for Idaho Batholith) were used to calculate allowable loads (TMDLs). Allowable exceedances of nutrient targets were not incorporated into the calculation of allowable loads, thereby adding a MOS to established allocations.
- Target values were developed to err on the conservative side of protecting beneficial uses. DEQ's nutrient assessment decision matrix for wadeable streams in mountainous regions of Western Montana considers impacts to both aquatic life/fishes and primary contact recreation, the two most sensitive beneficial uses affected by nutrient impairments. The assessment incorporates parameters representing physical (nutrient water chemistry), biological (e.g., periphyton and macroinvertebrates), and aesthetic (benthic algal growth concentrations) properties of these stream systems in a multi-tiered data analysis framework. Further, the nutrient assessment process considers both magnitude and frequency of nutrient target exceedances through the use of two statistical tests to help address nutrient uptake. Also, the number of allowable exceedances varies dependent on previous impairment status, taking a "guilty until proven innocent" approach for streams already considered to have water quality problems and to attempt to balance type I (alpha) and type II (beta) errors (Suplee and Sada de Suplee, 2011).
- Seasonality (discussed above) and variability in nutrient loading is considered in target, development, monitoring design and source assessment.
- An adaptive management approach (discussed below) is recommended to evaluate target attainment and allow for refinement of load allocations, assumptions, and restoration strategies to further reduce uncertainties associated with TMDL development over time.

5.8 Uncertainty and Adaptive Management

Uncertainties in the accuracy of field data, nutrient targets, source assessments, loading calculations, and other considerations are inherent when assessing and evaluating environmental variables for TMDL development. However, mitigation and reduction of uncertainties through adaptive management approaches is a key component of ongoing TMDL implementation and evaluation. The process of adaptive management is predicated on the premise that TMDL targets, allocations, and the analyses supporting them are not static, but are processes subject to modification and adjustment as new information and relationships are understood. Uncertainty is inherent in both the water quality-based and model-based modes of assessing nutrient sources and needed reductions. The main sources of uncertainty are summarized below.

Water Quality Conditions
It was assumed that sampling data for each waterbody segment are representative of conditions in each segment. Not all segments met the minimum sample size of 12 observations (for previously unlisted AUs) or 13 observations (for previously listed streams). Four of the waterbody segments did not have the desired sample size, but in most cases there were sufficient exceedances to make assessment decisions or to retain the previous listing. Future monitoring as discussed in **Section 10.3** should help reduce the uncertainty regarding data representativeness, clarify for streams with TMDLs for both nutrient forms (i.e., TN and TP) whether both forms have a role in causing excess algal growth, improve the understanding of the effectiveness of Best Management Practice (BMP) implementation, and increase the understanding of the loading reductions needed to meet the TMDLs.

It was also assumed that background concentrations are less than the target values, and based on sample data upstream of suspected sources and from other streams within the Bitterroot project area that are not impaired for nutrients, this appears to be true. However, it is possible that target values are naturally exceeded during certain times or at certain locations in the watershed. Future monitoring should help reduce uncertainty regarding background nutrients concentrations particularly in areas with recent burns and in the Threemile watershed.

6.0 METALS TMDL COMPONENTS

This portion of the document addresses all metals water quality impairments in the Bitterroot total maximum daily load (TMDL) Project Area. It includes:

- Metals designated use impacts
- Stream segments of concern
- Water quality data and information sources
- Metals impairment assessments and comparison to existing conditions
- Metals source assessments
- Metals total maximum daily loads and allocations
- Seasonality and margin of safety
- Uncertainty and adaptive management

6.1 EFFECTS OF METALS ON DESIGNATED BENEFICIAL USES

Metals concentrations exceeding the aquatic life and/or human health standards can impair support of numerous designated beneficial uses including: aquatic life, drinking water, and agriculture. Within aquatic ecosystems, metals can have a toxic, carcinogenic, or bioconcentrating effect on biota. Likewise, humans and wildlife can suffer acute and chronic effects from consuming water or fish with elevated metals concentrations. No waterbody applicable to this project has a fish consumption advisory more restrictive than the generic statewide guidelines established by Montana Fish, Wildlife and Parks (Montana Department of Public Health and Human Services et al., 2014). Because high metals concentrations can be toxic to plants and animals, impaired irrigation or stock water may affect agricultural uses.

6.2 STREAM SEGMENTS OF CONCERN

Two waterbodies in the Bitterroot TMDL Project Area are listed as impaired due to metals on the 303(d) list within the 2014 Integrated Report (see **Table 6-1**). These impairments are addressed by TMDLs developed in this document. In 2013, Department of Environmental Quality (DEQ) updated the impairment determinations of streams in the project area following additional data collection for the 2014 Integrated Report. Based on the new information, aluminum was added to the list of pollutants impairing water quality in Lick Creek and the existing lead listing on the lower segment of the Bitterroot River was verified.

Table 6-1. Metals impairment causes for the Bitterroot TMDL Project Area addressed via TMDL development within this document

Waterbody & Location Description	Waterbody ID	Impairment Cause	Cycle First Listed
Bitterroot River, Eightmile Creek to mouth (Clark Fork River)	MT76H001_030	Lead	2004
Lick Creek, headwaters to mouth (Bitterroot River)	MT76H004_170	Aluminum	2014

6.3 WATER QUALITY DATA AND INFORMATION SOURCES

Data used for impairment assessment and target evaluation was obtained from the U.S. Geological Survey (USGS), the Tri-State Water Quality Council, the Environmental Protection Agency (EPA), and the

Montana Department of Environmental Quality (DEQ). The primary information assembled was surface water quality data; groundwater and streambed sediment data were also reviewed. In accordance with DEQ's data quality objectives guidance, only data collected within the last 10 years was used for impairment assessment and target evaluation. Older data is considered descriptive and was used for source characterization, loading analysis and trend evaluation.

The dataset was further refined at the time DEQ assessed the impairment status of these waterbodies in 2013 by excluding data collected in 2003 even though the data were less than 10 years old. Upon thorough review, DEQ concluded that 2003 data was not representative of current water quality conditions due to the effects of widespread wildfires in 2000. That year, 17% of the total project area burnt with even larger portions affected in tributary basins (e.g., 53% in the East Fork Bitterroot Watershed) (Gibson and Morgan, 2009). USGS and DEQ partnered by establishing a network of sampling sites to assess the impacts of fires on water quality from 2001-2010 (Frankforter, Jill, personal communication, 2013[1]). Data collected as part of that effort show a high flow pulse of contaminants in the three years following the fire that eventually dissipated. Elevated metals concentrations were only observed during spring runoff conditions and were closely associated with total suspended sediment samples orders of magnitude greater than normal. These results appear to indicate that the 2000 wildfires temporarily introduced sediment bound metals into area streams and rivers at elevated levels; however the inputs were short lived and follow-up monitoring, including DEQ's basin wide sampling in 2012, could not reproduce many of the elevated metals concentrations observed from 2001-2003.

In summary, the Bitterroot River's assessment dataset of 68 water quality samples was comprised of Tri-State Water Quality Council samples collected in 2005, DEQ samples from 2004, 2005, and 2012, and USGS samples from 2004-2009. Lick Creek's assessment dataset of ten water quality samples and two streambed sediment samples, was collected by DEQ in 2004 and 2012, and EPA in 2013. The water column and sediment metals data used for analysis in this report is attached in **Appendix C**. Data summaries of relevant water quality and sediment quality parameters for each metals-impaired waterbody segment are provided in **Section 6.4.3**.

6.4 Metals Impairment Assessment and TMDL Determination

DEQ compiled the data described in **Section 6.3** and compared the data to water quality targets in order to assess the impairment status of each waterbody and determine which streams required TMDLs. This section presents the TMDL determination framework, the metals water quality targets used in the determinations, and the results of these determinations.

6.4.1 Metals TMDL Determination Framework

The process followed to determine whether a TMDL is necessary involves three steps:

1. Evaluate metals sources.
   Metals sources may be either naturally occurring or anthropogenic (i.e. human-caused). TMDLs are developed for waterbodies that do not meet standards, at least in part, due to anthropogenic sources.
2. Develop numeric targets that represent unimpaired water quality (**Section 4.1**).
   TMDL plans must include numeric water quality criteria or *targets* that represent a condition that meets Montana's ambient water quality standards. Numeric targets are measurable water

[1] Personal Communication between Jill Frankforter, U.S. Geological Survey, Water-Quality Unit Chief and Peter Brumm, Environmental Protection Agency 1/16/2013.

quality indicators. They may be used separately or in combination with other targets to represent water quality conditions that comply with Montana's water quality standards (both narrative and numeric). Metals targets are presented next, in **Section 6.4.2**.

3. Compare water quality with targets to determine whether a TMDL is necessary.
   DEQ determines whether a TMDL is required by comparing recent water quality data to metals targets. In cases where one or more targets are not met, the waterbody is considered impaired, placed on the 303(d) list, and a TMDL is developed. If data demonstrates no impairment, the waterbody – pollutant combination is recommended for removal from the 303(d) list and no TMDL is developed.

6.4.2 Metals Targets

Targets for metals-related impairments in the Bitterroot TMDL Project Area include both water chemistry targets and sediment chemistry targets. The human health and aquatic life criteria defined in DEQ Circular DEQ-7 (Montana Department of Environmental Quality, 2012) are use directly as water chemistry targets for these TMDLs. Sediment chemistry targets are adopted from numeric screening values for metals in freshwater sediment established by the National Oceanographic and Atmospheric Administration (NOAA).

6.4.2.1 Water Chemistry Targets

Human health criteria are intended to protect drinking water beneficial uses. Acute and chronic aquatic life criteria are intended to protect aquatic life uses and account for different durations of exposure. For any given pollutant, the most stringent of these criteria is adopted as the water quality target. Selecting the most stringent criteria as the water quality target ensures the protection of all designated beneficial uses. The aquatic life criteria for most metals are dependent upon water hardness wherein the criteria gradually increase, or becomes less stringent, as the water hardness increases. For the metal parameters of concern to this document, only lead is hardness dependent; aluminum criteria are constant. Water quality criteria (acute and chronic aquatic life, human health) for aluminum and lead at water hardness values of 25 mg/L and 400 mg/L are shown in **Table 6-2**. The targets are expressed in micrograms per liter, equivalent to parts per billion. Note that there is no numeric human health criterion for aluminum.

Table 6-2. Metals numeric water chemistry targets applicable to the Bitterroot TMDL Project Area

Metal of Concern	Aquatic Life Criteria (µg/L) at 25 mg/L Hardness		Aquatic Life Criteria (µg/L) at 400 mg/L Hardness		Human Health Criteria
	Acute	Chronic	Acute	Chronic	
Aluminum, Dissolved	750	87	750	87	N/A
Lead, Total Recoverable	13.98	0.545	476.82	18.58	15

Montana's numeric aluminum criteria only apply within a pH range of 6.5-9 standard units. Two aluminum samples used in this TMDL analysis were collected from waters slightly below pH 6.5. While this precludes use of the numeric criteria, general prohibitions within Montana's narrative standards still apply. Specifically, Administrative Rules of Montana (ARM) 17.30.637 states that "*…waters must be free from substances…that will: create concentrations or combinations of materials which are toxic or harmful to human, animal, plant or aquatic life…"*

Published literature confirms that aluminum is lethal to fish when pH is less than 6.5 (Baker and Schofield, 1982; Cleveland et al., 1986; Buckler et al., 1987; Hunn et al., 1987). Many studies have also shown increased aluminum toxicity as acidity increases (Baker and Schofield, 1982; Buckler et al., 1987).

Increased toxicity at low pH is common for all metals, not just aluminum. However, pH is particularly important with aluminum due to the increase in bioavailability that results from pH-induced changes in aluminum speciation (Buckler et al., 1987). Often the end result is a coagulation of aluminum hydroxides on gill surfaces leading to death of the individual fish (Cleveland et al., 1986).

Given the documented toxic effects in low pH situations, the chronic aquatic life criterion (87 µg/L) will be applied as the aluminum threshold for impairment determinations regardless of pH. In other words, the narrative statement contained in ARM 17.30.637 is translated to 87 µg/L. EPA has approved aluminum TMDLs in the past which have followed a similar rationale (Montana Department of Environmental Quality and U.S. Environmental Protection Agency, 2014; Montana Department of Environmental Quality, 2011). If, in the future, 87 µg/L is identified as an insufficient target to protect aquatic life, a revised translation of the narrative standard may be justified.

6.4.2.2 Metals Sediment Chemistry Targets

Metals concentrations in streambed sediments are used as supplementary indicators of impairment. Montana does not currently have numeric criteria for metals in stream sediments, although the previously mentioned water quality prohibitions found in ARM 17.30.637 prohibit metals concentrations in streambed sediments from creating toxic or harmful conditions to aquatic life. In addition to directly impairing aquatic life in contact with stream sediments, high metals concentrations in sediment commonly correspond to elevated concentrations of metals in water during high flow conditions. Where instream water quality data exceeds water quality targets, sediment quality data provide supporting information, but are not necessary to verify impairment.

In the absence of numeric criteria for metals in stream sediment, DEQ bases sediment quality targets on values established by the National Oceanic and Atmospheric Administration (NOAA). NOAA has developed Screening Quick Reference Tables for stream sediment quality, including concentration guidelines for metals in freshwater sediments. These criteria come from numerous studies and investigations, and are expressed in Probable Effects Levels (PEL). PELs represent the sediment concentration above which toxic effects to aquatic life frequently occur, and are calculated as the geometric mean of the 50th percentile concentration of the toxic effects data set and the 85th percentile of the no-effect data set (Buchman, 1999). PEL values are therefore used by DEQ as supplemental targets to evaluate ARM 17.30.637 and whether streams are *"free from substances…that will…create concentrations or combinations of materials that are toxic or harmful to aquatic life."* If the water quality targets are met but a sediment concentration is more than double the PEL (100% exceedance magnitude), this result can be used as an indication of a water quality problem and additional sampling may be necessary to fully evaluate target compliance. In rare cases, extremely high sediment concentrations can be used to list a waterbody where surface water exceedances have not been observed. **Table 6-3** contains the sediment chemistry targets (in parts per million) for the metals parameters of concern in the Bitterroot TMDL Planning Area. Note that aluminum does not have an established PEL value.

Table 6-3. Metals numeric sediment targets applicable to the Bitterroot TMDL Project Area

Metal of Concern	PEL (mg/kg or parts per million)
Aluminum	NA
Lead	91.3

6.4.3 Existing Conditions and Comparison with Metal Targets

For each waterbody segment included in the 2014 Integrated Report for metals (**Table A-1**), DEQ evaluated recent water quality and sediment data relative to applicable targets in order to assess the impairment status and make TMDL development determinations. The evaluation process summarized below is derived from DEQ's Monitoring and Assessment program guidance for metals assessment methods (Drygas, 2012).

- A waterbody is considered impaired if a single sample exceeds the human health target.
- A waterbody is considered impaired if more than 10% of the samples exceed the aquatic life target.
- A waterbody is considered not impaired a pollutant if the aquatic life target exceedance rate is equal to or less than 10%. A minimum 8 samples are required, and samples must represent both high and low flow conditions. Samples collected between April 15 and June 30 are considered high flow, all other times are considered low flow.
- There are two exceptions to the 10% aquatic life target exceedance rate rule: a) if a single sample exceeds the acute aquatic life target by more than a factor of two, the waterbody is considered impaired regardless of the remaining data set; and b) if the exceedance rate is greater than 10% but no anthropogenic metals sources are identified, management is consulted for a case-by-case review.

DEQ and EPA recently completed several years of water and stream sediment sampling in the Bitterroot TMDL Project Area to assist with these determinations. While DEQ reviewed impairment determinations and collected samples for numerous metal parameters (i.e., aluminum, arsenic, cadmium, chromium, copper, iron, lead, mercury, selenium, silver, and zinc), only streams where TMDLs are established in this document and their current 2014 303(d) listing are discussed below.

6.4.3.1 Bitterroot River (MT76H001_030)

The Bitterroot River, from Eightmile Creek to the mouth, has been included on the 303(d) list with lead listed as a cause of impairment since 2004. DEQ used recent metals water quality data to evaluate current conditions relative to the applicable targets. The available dataset consisted of DEQ data from 2004, 2005, and 2012, USGS data from 2004-2009, and Tri-State Water Quality Council data from 2005. Target exceedances only occurred during high flow conditions and only at the USGS gaging station near Missoula (12352500). All three of the samples DEQ collected in 2012 were at or below the lead detection limit, and the most recent target exceedance occurred five years ago, in June 2009. The water sample results are compared to targets in **Table 6-4.** While sediment data were not available, resuspension of lead in sediment may be a cause of water column exceedances because water quality targets were only observed during high flow conditions when suspended sediment concentrations were elevated.

Table 6-4. Bitterroot River Metals Data and Target Summary

Parameter	Pb
# Samples	68
Min	0.05 µg/L
Max	2.37 µg/L
# Acute Exceedances	0
Acute Exceedance Rate	0%
# Chronic Exceedances	11
Chronic Exceedance Rate	16%

Table 6-4. Bitterroot River Metals Data and Target Summary

Parameter	Pb
# Human Health Exceedances	0
Human Health Standard Exceedance Rate	0%

The dataset contains no human health or acute aquatic life exceedances, however more than 10% of the samples exceeded the chronic aquatic life target, therefore following the procedure outlined in **Section 6.4.2**, the Bitterroot River is considered impaired by lead and a TMDL is required. **Table 6-5** summarizes the TMDL decision factors.

Table 6-5. Bitterroot River Metals TMDL Decision Factors

Parameter	Pb
Number of Samples	68
Aquatic Life exceedance rate >10%?	Yes
Greater than 2x acute Aquatic Life exceeded?	No
Human Health Criterion exceeded?	No
NOAA PEL exceeded?	N/A*
Human-caused sources present?	Yes
2014 303(d) Listed?	Yes
TMDL developed?	**Yes**

*No metals sediment data exist to compare against PEL target

6.4.3.2. Lick Creek (MT76H004_170)

Lick Creek, from its headwaters to the mouth, was not assessed for metals impairment prior to the 2014 Integrated Report. DEQ used recent metals water quality data to evaluate current conditions relative to the applicable targets. The available dataset consisted of DEQ data from 2004, 2012, and 2013. The 2004 detection limit for aluminum was insufficient to compare against water chemistry targets, therefore the 2004 samples could not be used for analysis. Of the ten acceptable aluminum samples, two had corresponding pH values less than 6.5 standard units (i.e., 6.46 and 6.27) precluding the use of Montana's numeric chronic aquatic life criterion. However, as discussed previously in the metals target section (**Section 6.4.2.1**), these samples were included in the assessment based on an interpretation of the narrative standard. Concentrations were most elevated during high flow, but target exceedances occurred across both flow conditions. Water sample results are compared to targets in **Table 6-6**.

Table 6-6. Lick Creek Metals Data and Target Summary

Parameter	Al
# Samples	10
Min	46 µg/L
Max	320 µg/L
# Acute Exceedances	1
Acute Exceedance Rate	10%
# Chronic Exceedances	6
Chronic Exceedance Rate	60%
# Human Health Exceedances	N/A
Human Health Standard Exceedance Rate	N/A

EPA also collected metals sediment samples at three sites on Lick Creek in 2013. The only metal parameter to exceed sediment targets was lead; however, lead water chemistry data met targets with a sufficient dataset of 12 samples. Following the procedure outlined in **Section 6.4.2**, lead will remain unlisted but future monitoring is recommend to verify this impairment decision. No sediment samples were analyzed for aluminum because aluminum does not have an established PEL. One water chemistry sample for aluminum exceeded the acute aquatic life target and more than 10% of the samples exceeded the chronic aquatic life target, therefore following the procedure outlined in **Section 6.4.2**, Lick Creek is considered impaired by aluminum and a TMDL is required. **Table 6-7** summarizes the TMDL decision factors.

Table 6-7. Lick Creek Metals TMDL Decision Factors

Parameter	Al
Number of Samples	10
Aquatic Life exceedance rate >10%?	Yes
Greater than 2x acute Aquatic Life exceeded?	No
Human Health Criterion exceeded?	No
NOAA PEL exceeded?	N/A
Human-caused sources present?	Yes
2014 303(d) Listed?	Yes
TMDL developed?	**Yes**

6.5 Metals Source Assessments

Metals sources linked to human activity are typically related to the erosion of sediment bound metals from disturbed lands or related to mining activities. Metals related mining sources include adits and seeps, metals-laden floodplain deposits, waste rock and tailings, or other features associated with abandoned and inactive mining operations. Additional sources of metals may include wastewater treatment plants, historic and current air emissions, and industrial activities. The specific sources identified in each TMDL watershed are described below.

6.5.1 Bitterroot River (MT76H001_030)

Lead is rarely measurable in uncontaminated surface or groundwater, but the metal is found in substantial quantities within the Earth's crust. Lead is commonly found in sulfide, sulfate, carbonate, and oxide minerals (Lide, 2005). Generally more soluble under acidic conditions the presence and form of lead also depends on the ionic composition and the redox potential of receiving waters. USGS collected numerous years of paired total recoverable and dissolved lead samples at site 12352500 that indicate the dissolved fraction in the water column is negligible. This relationship, in combination with the fact that all lead exceedances in the Bitterroot River occurred during spring runoff conditions, points to a sediment-bound source of lead impairment either introduced into waterways from overland flow and erosion over the landscape or resuspension of contaminated sediment already existing within the stream channel. However, as described below, many potential lead sources investigated for this project were ultimately deemed insignificant and no single, obvious cause to the lead impairment is evident in the available dataset. The extensive wildfires that burnt the project area in 2000, which are briefly described in **Section 6.3**, may have introduced sediment-bound lead into the Bitterroot River but unlike other tributaries with a clear fire signature in their water chemistries, the river continued to exceed lead targets many years after the fires, as recently as 2009. Perhaps the spike in elevated lead is working its way through the system and after a few years' time, or even today, no new exceedances will be observed, but this theory is unconfirmed. Because there is still significant uncertainty as to the chief source of lead to the Bitterroot River, DEQ recommends additional monitoring and stresses a policy of adaptive management described in further detail in the **Sections 6.8** and **10.0,** while still moving forward with a TMDL at this time.

DEQ collected synoptic lead water samples throughout the Bitterroot basin in 2012 that included data from 13 tributaries and 6 sites on the mainstem. The Bitterroot River segment directly upstream of this impaired reach (MT76H001_020) was sampled nine times at four stations. All the samples collected on the middle segment were below the lead detection level of 0.5 µg/L. Compiling these nine non-detects with USGS's data collected at a site near Florence, MT (12351200), a sufficiently robust dataset of 21 lead samples is available to judge target compliance and the determination is clear: the middle segment of the Bitterroot River is not impaired by lead. As such, DEQ effectively assumes water at the boundary of these two steam segments is meeting lead water quality standards. Lead targets are the same for both segments because water hardness is consistent throughout the Bitterroot River. This conclusion then implies that the sources of lead responsible for the lower segment's impairment, and therefore investigated further below, are located in the lower watershed between Eightmile Creek and the mouth.

Only limited and dated sediment data are available on the lower segment of the Bitterroot River. Streambed sediments were analyzed for lead at one location near Missoula (12352500) in 1998 and 1999. Concentrations ranged from 49 to 53 mg/kg but were below the PEL target of 91.3 mg/kg. Another location closer to the mouth (C05BITTR01) was sampled in 2001 and once again, the concentration (15 mg/kg) did not exceed the PEL target. Also in 2001, a streambed sediment sample collected on O'Brien Creek, a western tributary that flows into the Bitterroot just above C05BITTR01, met the PEL target. This data, although over ten years old, is helpful to review from a source assessment perspective because no newer data exists; however, more recent streambed samples may show different results as a consequence of the 2000 fires. It is likely the 2001 sample was collected before the sediment and pollutant pulse from the burnt headwaters had time to migrate through the system and be picked up in the lower Bitterroot River dataset.

In 2006, US Fish and Wildlife Service (USFWS) collected soil and sediment samples from the streambank within the Lee Metcalf National Wildlife Refuge where automobiles were historically used as rip rap (Nelson, Karen, personal communication 2013[2]). This antiquated practice occurred elsewhere along the Bitterroot River and in other larger rivers throughout the state, but USFWS undertook the refuge study to address local concerns raised by the public over the physical and potential chemical hazards associated with the aging automobiles (sampling locations are within the USFWS land shown in **Figure 6-1**) (Howell, 2005). All USFWS samples were below the PEL target suggesting the rip rap is not a significant source of lead, but since these samples were not collected from the streambed, they do not address the concern that the available dataset may be missing a contaminated sediment pulse from the 2000 fires. Additional lead sediment samples throughout the watershed would benefit the source assessment.

Potential sources of the Bitterroot River's lead impairment investigated for this TMDL source assessment include a municipal separate storm sewer system (MS4), a wastewater treatment plant, and abandoned mines. Other sources may also include car bodies (briefly discussed above), the atmosphere, timber harvest, landfills, leaded gasoline, and outdoor recreation wastes. Lastly, a portion of lead is also attributable to natural sources.

[2] Personal communication between Karen Nelson, U.S. Fish and Wildlife Service and Peter Brumm, U.S. Environmental Protection Agency 12/3/13.

Missoula MS4

Under EPA's Stormwater Phase II Rule, Missoula is regulated as a small MS4 under a DEQ general permit (MTR040000). The MS4 permit area corresponds to the Missoula urban area, and includes areas under the jurisdiction of the City of Missoula, Missoula County, the University of Missoula, and Montana Department of Transportation. The City of Missoula has primary responsibility for the permit and the other entities are listed as co-permittees. Approximately 30% (10.92 square miles of 36.34) of the Missoula stormwater permit area lies within the Bitterroot River watershed. The remaining area drains to the Clark Fork River. Much of the stormwater generated within Missoula is managed by dry wells or sumps, which capture stormwater and drain it into the vadose zone, the unsaturated area below the ground surface and above the groundwater table. Other areas collect stormwater in storm sewers which discharge to surface water. Estimates of the total MS4 area that discharges to surface water vary from 15-30% or 5.4-10.9 square miles (Alban, 2012; Missoula City-County Health Department and Missoula Valley Water Quality District, 1997). DEQ analyzed the City of Missoula's Geographic Information System (GIS) coverage of the stormwater infrastructure, and determined that 7% (2.6 square miles) of the total MS4 area discharges runoff to this segment of the Bitterroot River. This area was then subdivided to classify portions as commercial (5%) or as residential (95%) to distinguish between varying degrees of impervious surface. The annual discharge was estimated using the stormwater discharge area of 2.6 square miles and the average annual precipitation of 14 inches. Based on consultation with DEQ modeling staff, the percentage of total annual precipitation that runs off to surface water was estimated as 40% for commercial areas and 8% for residential areas (Makus, Erik, personal communication 2014[3]). This results in an estimated annual discharge of 8,289,991 cubic feet or 234,746,424 liters of runoff generated by the MS4 which is delivered to the Bitterroot River.

The MS4 permit requires biannual sampling for metals, including lead, at the Bitterroot River outfall near the Highway 93 Bridge. DEQ also collected a grab sample from same outfall in June 2013. Additional data is available from the Missoula City-County Health Department who conducted a study of chemical deicer effects in the 1990s (Missoula City-County Health Department and Missoula Valley Water Quality District, 1997). The study included sampling of both stormwater outfalls and dry wells, and the contributing areas were characterized as commercial or residential. Although the deicer study's sampling locations are not identical to those required of the MS4 permit, comparison of these data suggest that lead concentrations in stormwater have declined considerably since the 1990s. In order to characterize current conditions, DEQ used the most recent data (2009-2013), excluding the deicer study samples, to estimate the existing lead load from the Missoula MS4. Based on this dataset, the average concentration of lead in stormwater runoff from commercial and residential areas is 14 µg/L and 3 µg/L, respectively, and the samples ranged from 1-30 µg/L. These concentrations greatly exceed the chronic aquatic life criterion for the Bitterroot River (0.57 µg/L) based on the average instream water hardness at USGS site 12352500 from 2004-2009. By multiplying the average concentrations by an area weighted discharge for commercial or residential zones and a unit conversion factor, DEQ estimates the Missoula MS4 contributes an annual lead loads of 2.82 lbs to the Bitterroot River.

DEQ did not find any existing information on the precipitation threshold required to initiate flow in the storm sewer outfalls, so 0.25 inches of precipitation was chosen as a reasonable representative value based on best professional judgment. Between 1984 and 2013, there was an average of 16 precipitation events greater than 0.25 inches per year. By dividing the estimated annual loads by 16, DEQ estimates that the per-event lead load (considered equivalent to a daily load given the short duration of storm and

[3] Personal communication between Erik Makus, Montana Department of Environmental Quality and Eric Sivers, Montana Department of Environmental Quality, 2014.

runoff events) is 0.18 pounds or 0.18 lbs/day. Note that this estimated stormwater load is not significant in comparison to existing instream loads (**Table 6-9**), or example TMDL loads (**Table 6-8**), particularly at the high flows when impairment conditions are of concern for this segment of the Bitterroot River. Under high flow conditions, this daily load value represents 0.2% of the existing Bitterroot River load or 0.6% of the TMDL. Also remember, DEQ estimates the MS4 does not discharge to the Bitterroot River some 349 days of the year (365 – 16 days with a rainfall event >0.25"). Therefore, for the majority of the time, the MS4's daily load contribution is effectively zero. Based on the existing high flow Bitterroot River load and the example allowable load (TMDL), it is apparent the overall lead loading from the Missoula MS4 is insignificant, however the permittee should continue to vigorously implement their stormwater management plan to address the considerably elevated lead concentrations observed in the sampling dataset. The town of Lolo, near the mouth of Lolo Creek, is a small urban area outside the Missoula MS4 boundary that may contribute stormwater to the Bitterroot River. No water quality data is available of the stormwater or the Bitterroot River in that reach to characterize the extent to which Lolo stormwater affects lead levels in the river.

Wastewater

The Lolo Wastewater Treatment Plant (WWTP) is a point source authorized by DEQ under Montana Pollutant Discharge Elimination System (MPDES) permit number MT0020168 to discharge directly to the Bitterroot River between Lolo Creek and Miller Creek. The plant, located at 1755 Lakeside Drive in Lolo, MT, is a minor publicly owned treatment works that employs activated sludge treatment of wastewater with UV disinfection of the effluent. Sludge is treated by aerobic digestion and stored in an aerated lagoon. Most recently, in 2012, sludge was removed from the lagoon, dewatered onsite, then hauled to a landfill in Missoula under EPA General Biosolids Permit MTG650000. Built in 1969 and upgraded in 1987, 2002 and 2006, the WWTP currently serves roughly 2,248 people. It discharges via a single outfall location and has a 1,291 foot long mixing zone for ammonia and dissolved oxygen (DEQ, 2014[4]). The facility currently has effluent limitations for biological oxygen demand, total suspended solids, and *E. coli*, but no specific limits for lead. For the permit cycle ending in 2012, the permittee was required to sample its effluent for lead twice a year in 2009 and 2010. The first required lead sample was mistakenly not collected. The remaining three samples were collected and all results were below the method detection limit (10 µg/L). Unfortunately, this method detection limit in discharge monitoring data was higher than the limit specified in the permit and the chronic aquatic life target, therefore the data could not be used to judge whether the facility is causing or contributing to the Bitterroot River lead impairment. In an attempt to address this data gap, EPA conducted sampling of the effluent in July and September of 2013 using appropriate detection limits. Lead concentrations of 0.6 and 0.8 µg/L were observed. These concentrations were below the chronic aquatic life target in the effluent, but because water in the Bitterroot River is characterized by very low hardness values, the effluent lead concentrations were slightly above the lowest lead target applicable to the river during high flow (0.57 µg/L). It is assumed lead discharge concentrations in the Lolo WWTP are relatively constant throughout the year and that the recent EPA monitoring data provide the best available characterization of this discharge. Using the average effluent discharge of 0.235 cfs and the average effluent lead concentration of 0.7 µg/L, the Lolo WWTP contributes and estimated 0.0009 lbs/day of lead to the Bitterroot River.

As a next step, the WWTP's load was compared to the total allowable load (TMDL) for the Bitterroot River to determine the WWTP's relative influence on water quality in the river. The nearest Bitterroot

[4] Permitting and Compliance Division, 2014. Authorization to discharge under the Montana Pollutant Discharge Elimination System (MPDES), Missoula County Commissioners Rural Sewer Improvement District #901. Permit #: MT0020168. http://deq.mt.gov/wqinfo/mpdes/minors/mt0020168per.pdf

River site downstream of the treatment plant that had more than one data point, USGS site 12352500, was used to represent instream conditions of the receiving waterbody. As shown in **Figure 6-1**, Miller Creek flows into the Bitterroot River between the Lolo WWTP and 12352500, however it is a small, intermittent creek that does not support flow year round. Additionally, the Miller Creek watershed has no active point sources and only one abandoned mine (Waldbilling), which DEQ Abandoned Mine Lands (AML) and the Montana Bureau of Mines and Geology (MBMG) have inventoried as a low priority and is unlikely to be a significant lead source. DEQ has collected five lead samples at various sites on Miller Creek in 2005 and 2012 and all sample results were below detection (0.5 µg/L). For these reasons, Miller Creek's impact on lead concentrations and loads in the Bitterroot River is assumed to be minimal, therefore 12352500 can be used to represent conditions in the river directly below the WWTP. All activities that included lead samples at 12352500 from 2004-2009 were incorporated into seasonal averages for hardness and flow. The relative high flow contribution is discussed here because that is the only time period instream exceedances have been observed, however contributions during low flow are similar.

During high flow, the average Bitterroot River discharge is 6,876 cfs and the average water hardness is 25.8 mg/L, which equates to a lead target of 0.57 µg/L based on the chronic aquatic life criterion. Multiplying this target by the river discharge and a unit conversion factor (0.0054), results in a maximum allowable load for the Bitterroot River of 21.1 lbs/day. Note, the river load mentioned here (21.1 lbs/day) does not match the example TMDL (27.00 lbs/day) presented in **Table 6-8** because hardness and flow values for this wasteload allocation (WLA) analysis were selected as averages from the USGS gage whereas **Table 6-8** presents loads calculated for the streamflow and hardness conditions when the highest lead sample was collected. These loading calculations show that the Lolo WWTP's load (0.0009 lbs/day) represents a mere 0.004% of the river's TMDL (21.1 lbs/day). Even if discharge was increased more than twofold to the current design capacity of 0.53 cfs, the plant would only contribute 0.010% of the TMDL. These results show that inputs from the treatment plant do not measurably increase the concentration in the Bitterroot River. Although concentrations of lead in the plant's discharge appear to be slightly above the target value, the flow difference (four orders of magnitude) drives the WWTP's load to be much smaller than the river's load. Thus it appears the Lolo WWTP is an insignificant source of lead to the Bitterroot River. Additional monitoring of the effluent using correct detection limits could help better characterize conditions since the conclusions here are based on limited data, and additional monitoring of Bitterroot River in the reach surrounding the WWTP could clarify the geographic extent of the lead impairment and conclude whether or not the river has assimilative capacity at the point of discharge. The new permit cycle requires the operator to monitor effluent for lead quarterly.

Abandoned Mines

Historically, a number of locations within the Bitterroot watershed were mined for lead and mining for other minerals occurred where parent material and tailings may contain lead. Several agencies, including MBMG, DEQ and USFS, have studied and are tracking reclamation efforts for mining-related metals sources in the Bitterroot River watershed (Hargrave et al., 2003; Pioneer Technical Services, Inc., 1995; Sylte and Mickelson, 2008). These studies documented metals contamination of soil, groundwater, surface water, and stream sediments for priority mine sites. In 1993, DEQ developed a prioritized list of abandoned mine locations to facilitate reclamation efforts of the worst sites first. Four priority abandoned mines sites were initially identified in the Bitterroot River watershed (see **Appendix A**, **Figure A-5**).

Reclamation was completed at both the Curlew and Ward Lode Mines in 1990s. The Bluebird and Montana Prince Mines still remain on the priority list but available information indicates that these locations were not mined for lead. The Montana Prince and Bluebird mines are unlikely major sources of lead because they are located outside the lower segment's basin and therefore water quality issues resulting from these sites would also be expected in the middle Bitterroot River segment, which is not the case. The Curlew Mine is also outside the lower segment basin, however, a longtime resident of the Bitterroot Valley informed DEQ at the public meeting for these TMDLs, that tailings from this mine were historically used as road building material throughout the watershed, including some places within the lower basin. Field samples collected at the Curlew Mine prior to the 1996 reclamation work identified lead concentrations in the tailings as high 16,000,000 ppb and averaging 1,870,000 ppb (Reeves, 2001). If material containing these extreme concentrations of lead were transported throughout the watershed, there may be numerous sites contributing lead to the Bitterroot River today that originated from the Curlew Mine. Further investigations are warranted on this subject. The Ward Lode Mine is located within the lower Bitterroot River segment basin in the tributary subbasin of Lolo Creek (see **Figure 6-1**). The surface water dataset for Lolo Creek below the Ward Lode Mine is small but indicates Lolo Creek is not elevated in lead. Additionally, EPA personnel visited and collected field parameters at the Montana Prince and Ward Lode Mines in October 2012 and found neither site contained apparent features likely impacting water quality. Besides these four priority abandoned mines, the Bitterroot watershed and the lower segment basin in particular, have numerous other abandoned or inactive hardrock mines.

One abandoned mine with lead listed as a commodity (Whaley Big Vein/ Blue Racer, MGMGID MI005555) could be a potential source of lead loading to the impaired reach and warrants further investigation. This mine is located on private land and drains to a small tributary of the Bitterroot River between Eightmile Creek and Lolo Creek. One Horse Mine (MBMGID RA006913) should also be investigated further. This mine is located along the upper impaired watershed boundary, on the western side. Lead was listed as a commodity, and a single historical observation indicated an elevated lead concentration in One Horse Creek (12.7 µg/L dissolved lead measured by MBMG, October 6, 1997). The GIS data show another abandoned mine, Wild Maple (MBMGID RA007102), near One Hose mine, however, the data indicate that the location information was inaccurate, and this mine may not be located in the One Horse Creek drainage area. Whaley Big Vein/Blue Racer and One Horse Mine are two examples of abandoned mines within the impaired reach watershed where further data collection is needed to determine whether abandoned mines are contributing to the lead impairment. Because there is currently no indication that abandoned mines are supplying lead to surface waters, no wasteload allocation is provided for this source although any associated overland flow loading would be captured under the composite load allocation to the lower segment basin.

Other Human Sources

Additional sources with the ability contribute lead to surface waters include the atmosphere, timber harvest, landfills, leaded gasoline, and outdoor recreation wastes. These are briefly described in the following paragraphs starting with the atmosphere. Atmospheric lead can sorb to sediment and then erode, becoming a source of lead loading to surface waters (U.S. Environmental Protection Agency, 2014). Background aerial deposition levels are naturally low but can be elevated near certain human activities, such as metal smelting facilities. No smelters have ever operated in or directly upwind of the watershed. The topography of the Missoula Valley contributes to the formation of significant weather inversions, especially during the winter months, that restrict pollutants from dispersing out of the valley. As a result, DEQ has identified the region as a non-attainment area for air quality, although not specifically for lead. Air quality has improved in the last decade, and it is assumed that lead deposited from the atmosphere is relatively minor, most of which occurs in the urban area and thus is captured in the MS4 contributions.

A large portion of the impaired reach watershed consists of land managed by the USFS and, to a lesser extent, owned and managed by private timber companies. Forest harvesting activities, unpaved roads, and other land disturbance may result in additional lead loading from erosion and sediment delivery beyond background loading. Loading from these and other land uses are expected to be minor and not a source of impairment.

The Billingsley Placer Mine operates a hard rock mining operation under a MPDES stormwater permit (MTR000529) along Lolo Creek. Rock is extracted and then crushed into gravel. Timber operations also occur on this site. Depending on the lead content of the sediment in the disturbed areas, the site may contribute a small amount of lead during storm events through overland flow. However, given that several observations downstream of the site indicate that lead concentrations are below detection in Lolo Creek, this site is not considered a significant source of lead to the Bitterroot River.

There are at three historic landfills or waste disposal sites adjacent to the river near Missoula with unknown construction techniques and contents, potentially leaking elevated lead through groundwater pathways. One landfill, the Norm Close Landfill, is bordered by the Highway 93 Bridge and the western bank of the Bitterroot River. The landfill is no longer active and no information is available on the characteristics of this site. Slightly more information is known about the other two sites, which are located just downstream of the bridge and downstream of where lead exceedances were observed in the Bitterroot River. These two sites were investigated under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) or 'Superfund' program in the 1990s. The first, Fort Missoula, is a 45-acre site operated intermittently as a military facility since 1877 that has two historic landfills and a leach pit that received discharge from an oil-water separator and a vehicle washing station; both are located in the floodplain (Montana Department of Environmental Quality, 1997). DEQ has ranked the facility as a medium priority and the Department of Defense is listed as the lead agency for cleanup. No work has been undertaken since the initial screening in the 1990s and there is no lead data available for this site. In a similar scenario, the Missoula Vocational Tech Center historically disposed of shop wastes in a dry well and septic drain field. Tanks, which emptied into the dry well and drain field, contained sludge with high levels of heavy metals, including elevated lead (560 ppm). The Missoula Valley Water Quality District noted soils around the facility were contaminated with petroleum hydrocarbons (Montana Department of Environmental Quality, 2002). DEQ also ranked this facility as medium priority and will address it when higher priority facilities have been resolved. Because these sites are located downstream of the only water quality monitoring site with lead exceedances, and the loading pathway does not support the seasonality and sample fraction of observed surface water exceedances (i.e., only high flow exceedances and overall low dissolved fraction) follow-up investigations of these sites is recommended but they are not considered significant sources of lead to the Bitterroot River.

Lead was traditionally used as an additive in gasoline prior to a national ban 1995 and fuel spills or leaking underground storage tanks could still be contributing lead to the river. The underground storage tank nearest to the monitoring station with observed exceedances (12352500) belongs to a gas station located 1,200 feet east of the river off Highway 93. This facility owns three tank that were last inspected in November 2012 and were not leaking at that time (Montana Department of Environmental Quality, 2014b; 2014c). According to information provided by the Petroleum Tank Release Cleanup Fund, numerous other tanks in the urban-Missoula portion of the Bitterroot watershed have had petroleum spills or leaks with an unknown impact to the Missoula Aquifer and Bitterroot River. Similar to the landfills in that a groundwater source does not support the observed surface water exceedance pattern, historic releases of leaded gasoline are not considered the cause of the Bitterroot River's lead impairment.

The last potential human source of lead investigated for this project, deemed to be minor, and not given a separate allocation in the TMDL, is the load introduced from leaded fishing weights and ammunition. The Bitterroot River is a popular fishing location, however, the state has failed to find a correlation between lead impairment and fishing pressure in other waterbodies throughout the state. Additionally, the localized nature of water quality exceedances at one monitoring site does not support a linkage with an activity that is distributed across the stream reach like fishing. Lead shot, although illegal for waterfowl hunting, may be a problem at shooting ranges if not properly collected and disposed of (U.S. Environmental Protection Agency, 2003). Many studies have documented elevated lead concentrations in the soils and surface waters of shooting ranges where lead shot is most concentrated and exposed to weathering (Jorgensen and Willems, 1987; Craig et al., 1999; Cao et al., 2003). Additionally, the mobility of lead in soils has been shown to increase under acidic conditions (Cao et al., 2003). A sporting clay shooting range operated from 1996-2006 in the Bitterroot River floodplain just north of the Eightmile Creek confluence. The land has since been purchased by a land preservation and restoration organization (MPG Ranch) that conducts focused environmental research on the property. One such investigation analyzed soil samples at range sites suspected to have the highest likelihood of contamination. Sample results indicated acidic soils and elevated levels of sulfur and lead in some places. The highest lead soil sample observed at MPG Ranch was 466 mg/kg (or ppm), which is above the streambed sediment TMDL target of 91.3 mg/kg discussed in Section 6.4.2.2 but not as concentrated as levels seen in other studied ranges (> 1,000 mg/kg) with recognized contamination issues (Cao et al., 2003)(McTee, Mike, personal communication 2014[5]). MPG Ranch has since taken steps to restore the range and continues to study and address issues at the site. Initially, some range soils were removed from the floodplain and placed in an offsite, capped, repository. Later, in 2012, lime was added to the remaining range soils to increase soil pH and reduce the mobility of lead, thereby reducing the chance that lead is migrating to surface or groundwater pathways (McTee, Mike, personal communication 10/23/2014[5]). Because the only known shooting range in the lower Bitterroot River watershed is being actively addressed, pollution from lead ammunition is not considered a significant source of lead to the Bitterroot River.

Natural Background

The final source of lead that requires considerations is the natural background load contributed from the chemical and physical weathering of igneous and metamorphic rocks and soils (U.S. Bureau of Reclamation, 2009), and atmospheric deposition, typically from volcanic eruptions (U.S. Environmental Protection Agency, 2014). Because there are no volcanos upwind, atmospheric deposition is estimated to be minimal, and most contributions attributed to natural sources are likely related to geology and soils of the surrounding area. Within the Bitterroot TMDL Project Area, naturally-occurring metals concentrations area derived by using the lower quartile of surface monitoring data collected since 2004. This quantification process is described later in **Section 6.6.2**. Groundwater concentrations and other reference values are used as supporting lines of evidence.

[5] Personal communication via phone call from Mike McTee, Project Coordinator and Restoration Research, MPG Ranch and Peter Brumm, Environmental Protection Agency 10/23/2014

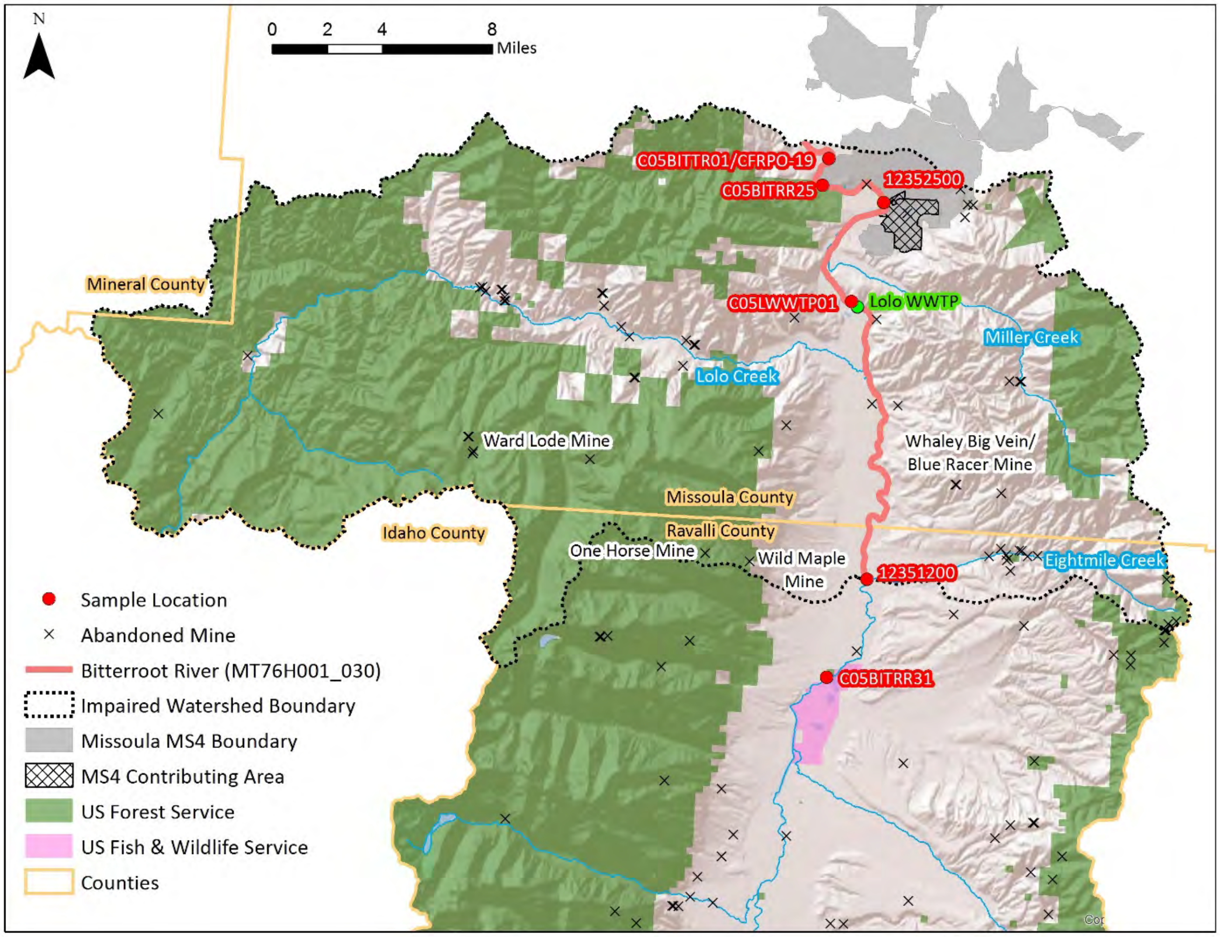


Figure 6-1. Metals sources and sample locations on the impaired reach of the Bitterroot River

6.5.2. Lick Creek (MT76H004_170)

Aluminum occurs naturally in water, soil, and bedrock, and is the third most abundant element in the Earth's crust. Aluminum never exists naturally in its elemental state; rather, it is found in soil and bedrock as either soluble or insoluble compounds such as oxides, sulfides, or hydroxides. Aluminum is found in many common minerals, including feldspars, granite, cryolite, and bauxite (Lide, 2005). Between a pH of 6.5 and 9 in freshwater, aluminum can exist in a dissolved state, as a hydroxide, or as a complex with humic acids, phosphate, sulfate, or other anions. When part of a soluble compound, the metal is more soluble in water under either acidic or basic conditions compared to neutral conditions (U.S. Environmental Protection Agency, 1988).

Aluminum can be delivered to surface waters through sediment loading in runoff from either natural or disturbed land. The aluminum content in underlying bedrock affects the potential for loading to surface water. Raines et al. (1996) developed a spatial coverage and rating for the metals content of bedrock in the Pacific Northwest. One of the spatial coverages provides a rating for aluminum content in bedrock based on typical mineralogy and weathering processes. Geological formations were categorized as low, medium, and high aluminum content or unclassified (e.g., alluvial areas). The underlying bedrock for the majority of the Lick Creek watershed (all but the alluvial portion) fell into the high aluminum content category based on the intermediate igneous formation underlying the watershed. The report defines a high classification as potentially less favorable to aquatic life but does not go so far as saying toxic conditions are expected. Especially given the high aluminum content of the underlying geology, groundwater supplements to Lick Creek are another potential background source. Based on data downloaded from the MBMG Groundwater Information Center, one groundwater aluminum sample is available within the Lick Creek watershed. The sample did not detect aluminum (<30 µg/L), potentially indicating that groundwater concentrations are not elevated, however, the dataset is too small to draw any meaningful conclusions from by itself.

Looking at a larger dataset of data downloaded from the EPA/USGS water quality portal, that included 129 surface water samples collected in the Bitterroot watershed and analyzed for dissolved aluminum since 1974, all but nine met the aluminum chronic aquatic life criterion and seven of those nine exceedances were from Lick Creek. For example, Tin Cup Creek, located just five miles south of Lick Creek on the east side of the Bitterroot Mountains overlaying similar geology, was sampled four times spanning various flow conditions by DEQ in 2012 and met all aluminum targets with concentrations ranging from 19 µg/L to 60 µg/L. This dataset indicates that, opposed to elevated concentrations of aluminum resulting from regional geology, conditions localized to the Lick Creek watershed may be contributing to the extremely elevated aluminum concentrations observed in the creek.

Anthropogenic sources that may contribute aluminum through accelerated soil erosion within the watershed include forestry, unpaved roads, off-road vehicle use, agriculture, and mining. No permitted point sources exist in the Lick Creek watershed, nor has any historic mining occurred according to DEQ and MBMG databases. While the majority of the watershed is forested, small properties with hay or pasture exist on privately owned land surrounding the Lick Creek Road monitoring station (C05LICKC01). Aerial imagery of this area shows sparsely vegetated land near the creek where overland flow erosion is likely occurring. Aluminum in livestock feed could be an additional source of aluminum although it is unlikely that livestock are present in substantial numbers.

The majority of the Lick Creek watershed drains forested land cover within the boundaries of the Bitterroot National Forest including the Lick Creek Demonstration/Research Forest. In order to characterize any potential impacts to water quality as a result of historic land management, activities undertaken at this demonstration forest were investigated (Carlons and Floch, 1996; U.S. Forest Service, 2013). Between 1907 and 1911, a total of 2,135 acres were harvested, notable for representing the first large national forest timber sale of ponderosa pine in the USDA Forest Service Northern Region. The USFS has monitored vegetation succession since the harvest. In earlier years, understory vegetation became denser than during the pre-harvest period due, in part, to fire suppression activities. In the 1950s and 1960s, additional harvesting was performed on 468 acres of the originally harvested land. In more recent years, experimental prescribed burns and thinning practices have helped to control vegetation density (Carlons and Floch, 1996; Gruell et al., 1982). A USFS action is currently under review that would perform a commercial harvest of about 1,860 acres, construct 0.8 mile of road, thin about 330 acres, and conduct prescribed burns on about 3,000 acres. A portion of these activities would occur within the Lick Creek watershed. This project, entitled Como Forest Health Project, seeks to improve age and species diversity, reduce fire hazards, control pests, and maintain recreational uses (Federal Register, 2013).

Forest harvesting and prescribed burns are performed periodically, which may disturb some soil and cause erosion. However, the prescribed burns and thinning practices reduce the risk of wildfire, which can cause severe erosion and sediment loading to the creek. The most recent wildfire occurred in 2000 and burnt a portion of Lick Creek's headwaters region (Geospatial Multi-Agency Coordination Group, 2014). The National Forest land contains a network of unpaved forestry roads that may contribute to sediment loading in the watershed. Unauthorized off-road vehicle access had occurred on USFS land previously causing excessive erosion; a trail is now available for off-road vehicles and compliance with motor vehicle rules are enforced (U.S. Forest Service, 2013). There has been no livestock grazing on National Forest lands in the Lick Creek watershed since 1975. Prior to that time, livestock grazing was mostly confined to creek bottoms as much of the upland is too steep and densely forested (Gruell et al., 1982).

During 2012 and 2013, Lick Creek was sampled for aluminum at three locations (C05LICKC01, C05LICKC02, C05LICKC03; **Figure 6-2**). Aluminum was detectible but did not exceed targets at the headwaters site (C05LICKC03). Six of the seven samples collected at the downstream sites (C05LICKC01 and C05LICKC02) did exceed targets. Low but detectible concentrations of aluminum (25 to 55 µg/L) were also measured in Lost Horse Creek Canal (C05LHCCN01), which transfers water into the Lick Creek basin from the Lost Horse Creek drainage to the north. When the canal is in use, water is diverted to irrigate pasture lands and minimal flows, if any, are directly discharged to Lick Creek. This trans-basin diversion may contribute flow and a small aluminum load to the lowest stretches of Lick Creek through groundwater supplements or overland flow from flood irrigation, however, because concentrations of aluminum in the canal are well below targets, water transported into the basin via the Lost Horse Creek canal is not considered a significant source of aluminum by itself. Irrigation canal flows may actually have a diluting effect on Lick Creek as paired samples from C05LICKC03 and C05LICKC02 show aluminum concentrations decrease between the sites where these flow supplements are expected to occur.

Given the pattern of target exceedances, it is logical to examine changes in land use and environmental conditions between sites C05LICKC03 and C05LICKC01. Moving downstream, the forested landscape managed by the USFS transitions into smaller parcels of private ownership managed for irrigated pasture, light livestock use and private residence discussed above. These land uses could potentially be contributing aluminum to Lick Creek through elevated rates of erosion. A log home construction business is located downstream of C05LICKC01, but the site is not considered a significant source of aluminum because the greatest target exceedances were observed upstream of this location. A prominent mineral lick, which is thought to give Lick Creek its name, exists downstream of the Lake Como Road crossing and is a potential aluminum source during rain events and spring runoff time periods. In June 2013, an aluminum concentration of 446 µg/L was observed in the tributary draining the mineral lick (C05LICKT01), but the tributary was dry upon additional site visits in July and September of that year. While the tributary exhibits extremely elevated aluminum concentrations, because the tributary's streamflow (0.1 cfs) is minimal compared to Lick Creek (3.39 cfs), measured at C05LICKC03, a simple mixing calculation shows that the tributary itself would not cause a measurable increase in Lick Creek lead concentrations below their confluence. This rough calculation and the fact that aluminum target exceedance occurred in Lick Creek when this mineral lick-influenced tributary stopped flowing in the late summer months, indicate other sources exist, potentially including other mineral licks in the area not currently mapped. The source assessment performed for this TMDL effort was not able to clearly identify the chief source of aluminum to Lick Creek. Additional water quality monitoring between sites C05LICKC03 and C05LICKC01 and focused investigations into areas of mineralized geology could help refine the aluminum source assessment for Lick Creek. As such, DEQ stresses the adaptive management policies outlined in **Sections 6.8** and **10.0** to account for this uncertainty.

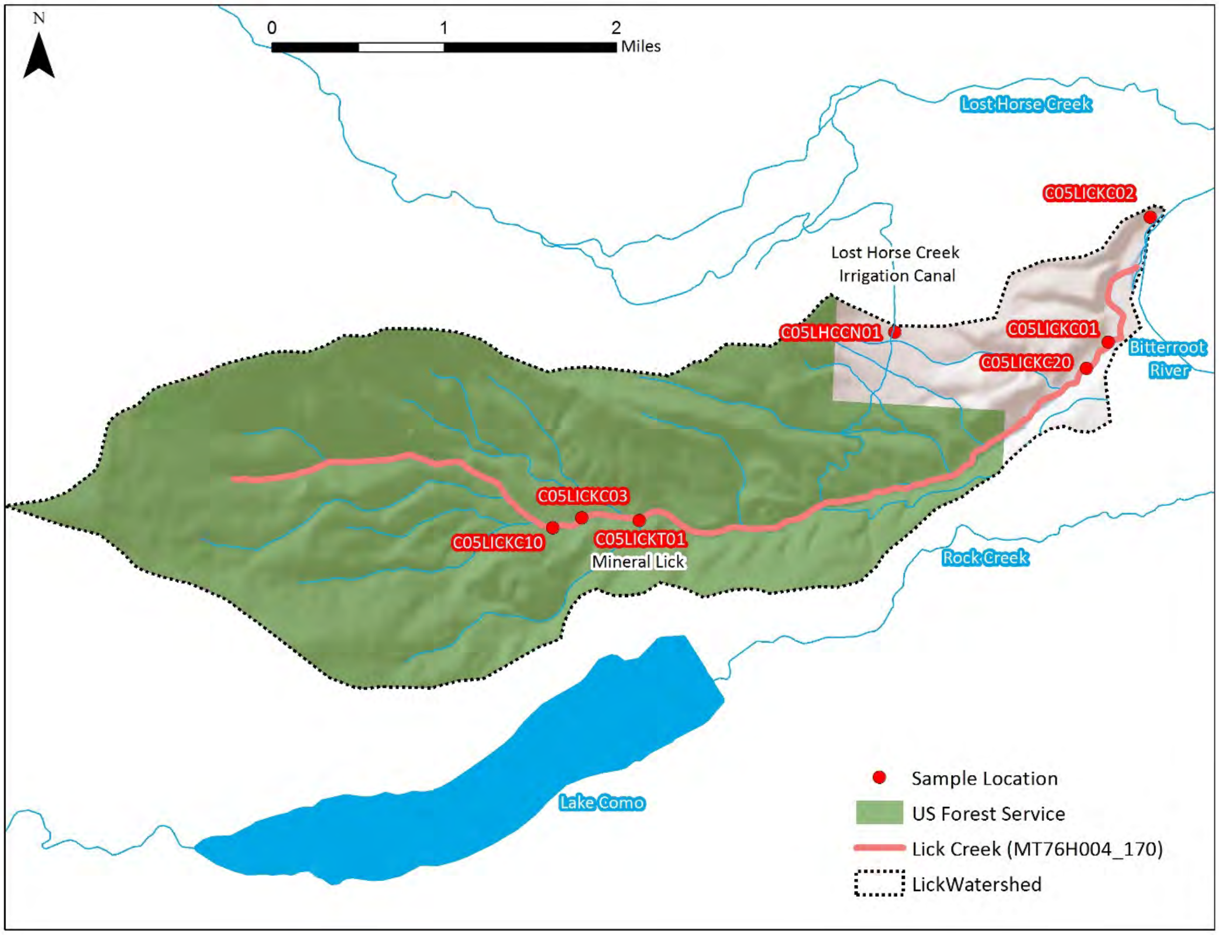


Figure 6-2. Sampling locations in the Lick Creek watershed

6.6 Metals TMDLs and Allocations

The following two sections explain the general process by which metals TMDLs are calculated and allocated, and walk through the steps DEQ followed to derive TMDLs and allocations for each metals impaired waterbody in the Bitterroot TMDL Project Area.

6.6.1 Metals TMDLs

This document presents metals total maximum daily loads for the lower segment of the Bitterroot River and Lick Creek. TMDLs are based on the most stringent water quality criterion (adopted as the water quality target), the water hardness (if applicable), and the streamflow. Using the most stringent target ensures the TMDLs are protective of all designated beneficial uses. TMDLs apply to any point along the waterbody and therefore protect uses along the entire stream. Target development is discussed in detail above, in **Section 6.4.2.**

Because streamflow and hardness vary seasonally, the TMDL is not expressed as a static value, but as an equation of the appropriate target multiplied by flow. These variable TMDLs are illustrated in **Figure 6-3** over a range of flow conditions at a water hardness of 25 mg/L. The TMDL under a specific flow condition is calculated using the following formula:

TMDL = (X) (Y) (k)

TMDL= Total Maximum Daily Load in lbs/day
X= lowest applicable metals water quality target in µg/L
Y= streamflow in cubic feet per second
k = conversion factor of 0.0054

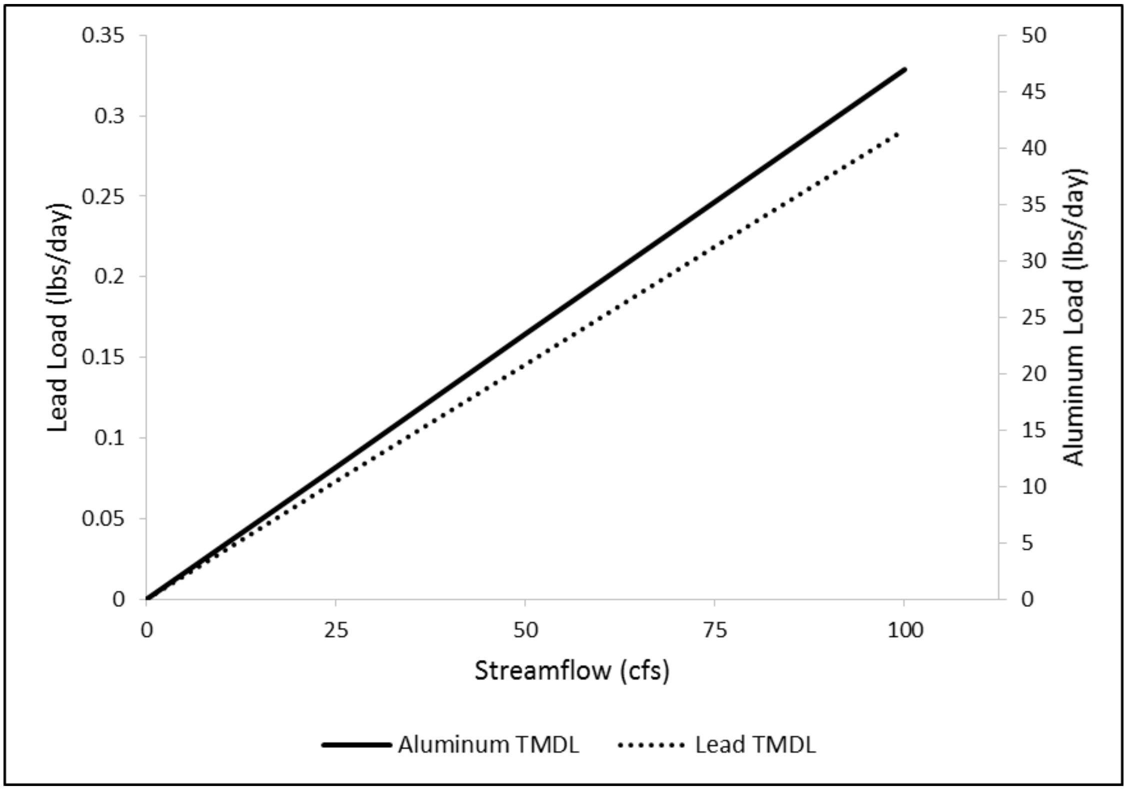


Figure 6-3. Aluminum and Lead TMDLs as a function of flow at 25 mg/L hardness

Table 6-8 provides example TMDLs and the load reduction requirements necessary to meet the TMDL for each metal impaired waterbody in the Bitterroot TMDL Project Area based on existing monitoring data. DEQ selected the highest measured lead or aluminum concentration, and the corresponding water hardness and streamflow for each flow regime to represent existing conditions. The highest lead concentrations for the Bitterroot River were collected at 12352500 on 5/19/2009 and C05BITTR01 on 7/27/2004. The highest aluminum concentrations for Lick Creek were collected at C05LICKC01 on 6/14/2013 and 7/27/2013.

The required percent reduction in total load is calculated by subtracting the TMDL from the existing load (measured concentration multiplied by flow multiplied by 0.0054), and dividing the difference by the existing load. In cases where the TMDL appears to be met during certain flow conditions, the percent reduction is reported as 0%. Because the highest observed concentration was used to calculate example TMDLs, the reductions presented here are higher than what is necessary to meet water quality targets at other times captured in the dataset. Setting the goal of meeting water quality targets 100% of the time when chronic aquatic life criteria allow a 10% exceedance rate, is a deliberate conservative approach that grants DEQ a margin of safety further discussed in **Section 6.7.2**.

Table 6-8. Detailed inputs for example TMDLs in the Bitterroot TMDL Project Area

Stream	Station	Discharge (cfs)		Hardness (mg/L)		Metal	Measured Conc. (µg/L)		Target Conc. (µg/L)		TMDL (lbs/day)		% Required Load Reduction To Meet TMDL*	
		High Flow	Low Flow	High Flow	Low Flow		High Flow	Low Flow	High Flow	Low Flow	High Flow	Low Flow	High Flow	Low Flow
Bitterroot River (MT76H001_030)	12352500	9,260	750	25	77	Lead	2.37	2	0.54	2.28	27.00	9.23	77%	0%
Lick Creek (MT76H004_170)	C05LICKC01	12.92	2.25	25	25	Aluminum	776	297	87	87	6.07	1.06	88%	71%

*Based on highest single sample concentrations (2004 through 2013)

6.6.2 Metals Allocations

As discussed in **Section 4.0**, a TMDL equals the sum of all the wasteload allocations (WLAs), load allocations (LAs), and a margin of safety (MOS). WLAs are allowable pollutant loads that are assigned to permitted and non-permitted point sources. Mining-related waste sources (e.g. adit discharges, tailings accumulations, and waste rock deposits) are non-permitted point sources subject to WLAs. LAs are allowable pollutant loads assigned to nonpoint sources and may include the pollutant load from naturally occurring sources, as well as human-caused nonpoint loading. Where practical, LAs to human sources are provided separately from naturally occurring sources. In addition to metals load allocations, the TMDL must also take into account the seasonal variability of metals loads and adaptive management strategies in order to address uncertainties inherent in environmental analyses.

These elements are combined in the following equation:

TMDL = ∑WLA + ∑LA + MOS

WLA = Wasteload Allocation or the portion of the TMDL allocated to metals point sources

LA = Load Allocation or the portion of the TMDL allocated to nonpoint metals sources and naturally occurring background

MOS = Margin of Safety or an accounting of uncertainty about the relationship between metals loading and receiving water quality

An implicit margin of safety (i.e., MOS = 0) is applied to the metals TMDLs in this document through the use of conservative assumptions throughout the TMDL development process described in greater detail in **Section 6.7.2**. In the sections that follow, load and wasteload allocations are provided for each waterbody-pollutant combination for which a TMDL is prepared (see **Table 6-1**). The allocations and existing loads are presented in **Tables 6-9** through **6-12**. Load estimations and allocations are based on a limited data set and are assumed to approximate general metals loading during high and low flow conditions. Due to the limited number of samples, existing load examples are based on the highest detected pollutant concentration for each flow regime and the corresponding flow from that sampling event.

The TMDL and allocation tables in the following sections give example TMDLs for each metal pollutant parameter under both high and low flow conditions for each stream segment. The TMDLs are calculated according to the TMDL formula (provided in **Section 6.6.1**) of lowest target concentration multiplied by the flow, multiplied by a unit conversion factor of 0.0054, to arrive at units of pounds per day. For example, the lead TMDL in the Bitterroot River under high flow conditions is 27.00 pounds per day which is found by multiplying the observed flow (9,260 cfs) by the target concentration (0.54 µg/L) and the unit conversion factor (0.0054).

6.6.2.1 Bitterroot River (MT76H001_030)

Allocations for this segment of the Bitterroot River include a composite load allocation to the watershed upstream of the impaired reach (LA_{UW}), a load allocation to natural background sources (LA_{Nat}), a load allocation to nonpoint sources (LA_{NPS}), a wasteload to Missoula's separate storm sewer system (WLA_{MS4}), and a wasteload to Lolo's wastewater treatment plant ($WLA_{LoloWWTP}$). These allocations are described below and expressed by the following formula:

$$TMDL_{Bitterroot} = LA_{UW} + LA_{Nat} + LA_{NPS} + WLA_{MS4} + WLA_{LoloWWTP}$$

Bitterroot Upper Watershed Composite Allocation
A composite allocation is given to all point and nonpoint sources located in the upper Bitterroot Watershed above the impaired reach. The proportion of load allocated to this source area was estimated by calculating the proportion of flow at USGS gage 12351200 (Bitterroot River near Florence, MT) versus USGS gage 12352500 (Bitterroot River near Missoula, MT). Flows could not be compared on the same dates chosen to represent high and low flow example TMDLs (June 6, 2012 and August 24, 2012) because the Florence gage was discontinued in September 2011. Thus the relationship was calculated by utilizing paired daily mean discharge data from January 2004 to December 2010. This period was selected in order to use full year datasets and avoid any seasonal bias in the average ratio. The average and median proportion of flow at gage 12351200 were 0.87 and 0.86, respectively. These values are similar to the drainage area ratio of the watershed upstream of the impaired reach compared to the entire watershed, which is 0.82. The average proportion of 0.87 was multiplied by the TMDL load to calculate the allocation to the upper watershed. The example WLAs below are based on the high flow and low flow TMDL examples provided in **Table 6-8**.

High Flow:
LA_{UW} = TMDL x 0.87 = 27.00 x 0.87 = 23.49

Low Flow:
LA_{UW} = TMDL x 0.87 = 9.23 x 0.87 = 8.03

Natural Background
Naturally occurring sources are provided a load allocation in pounds per day based on naturally occurring metals concentrations and streamflow. As defined in Administrative Rules of Montana (ARM) 17.30.602, naturally occurring sources include metals loading from non-human (natural background) sources as well as ”those sources from developed areas where all reasonable land, soil and water conservation practices have been applied.” The underlying assumption is that natural background sources alone would not result in metals target exceedances in the water column or streambed sediments. If future monitoring proves this to be incorrect, these TMDLs may need to be revised in accordance with the adaptive management strategy outlined in **Section 6.8**. Within the Bitterroot TMDL Project Area, naturally-occurring metals concentrations are derived by using the lower quartile of surface monitoring data collected since 2004. Groundwater concentrations and other reference values are used to support the derivation.

Water quality observations representing naturally occurring conditions were not available within the Bitterroot Project Area. Few water quality observations were available that could be separated from elevated human-caused loading. To estimate natural background conditions, the 25th percentile lead concentration of a larger, non-reference dataset was selected. This technique has been used in previous Montana TMDLs when reference sites are not available (U.S. Environmental Protection Agency, 2003). All total recoverable surface water samples of lead collected in the Bitterroot watershed hydrologic unit (17010205) since 2004 were downloaded from the national Water Quality Portal (U.S. Geological Survey and U.S. Environmental Protection Agency, 2014) and included in the analysis. Non-detect results were represented as detection limits in the calculation. The 25th percentile of this dataset, 0.3 µg/L, is assumed to be a reasonable representation of the natural total recoverable lead concentration in the lower Bitterroot Watershed. This agrees well with the background concentration used for the Flint Creek lead TMDL (0.25 µg/L) which was based on the 75th percentile of observed concentrations from a reference dataset (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012a).

Since the allocation to the upstream watershed (LA_{UW}) includes natural background sources for that portion of the drainage area, the allocation to natural background here was calculated specifically for the impaired reach. The example LAs for natural background were calculated using the example high and low flow discharges from **Table 6-8** and applying the background concentration of 0.30 µg/L lead, the conversion factor of 0.0054, and the lower basin flow proportion as follows:

High Flow:
LA_{Nat} = 9,260 cfs x 0.30 µg/L x 0.0054 x (1-0.87) = 1.95 lbs/day

Low Flow:
LA_{Nat} = 750 cfs x 0.30 µg/L x 0.0054 x (1-0.87) = 0.16 lbs/day

Missoula MS4 (MTR040007)
Per EPA guidance (U.S. Environmental Protection Agency, 2002), the Missoula MS4 (MTR040007) is assigned a wasteload allocation (WLA_{MS4}) for lead. The permit does not include effluent limits, but requires the development and implementation of a stormwater management plan to minimize loading to surface waters. The management plan must include six minimum control measures:

1. Public education and outreach
2. Public involvement/participation
3. Detection and elimination of illicit discharges
4. Control of stormwater runoff from construction sites
5. Management of post-construction stormwater in new development or redevelopment
6. Pollution prevention/good housekeeping

Additionally, the permit requires semiannual sampling in two locations, one that represents a residential area, and the other that represents a commercial area. The permit's commercial sample site is located within the MS4 area draining to the Bitterroot River, specifically at the outfall just north of the Highway 93 Bridge.

As discussed in **Section 6.5.1**, DEQ estimates that this portion of the Missoula MS4 may contribute lead loads of 2.82 lbs annually and 0.18 lbs daily. Lead concentrations in the stormwater have dropped significantly since the 1990s (Missoula City-County Health Department and Missoula Valley Water Quality District, 1997). DEQ believes this demonstrates a reduction in stormwater-related metals loading to the Bitterroot River due to stormwater controls and the leaded gasoline ban, but that further reductions are possible via full implementation of stormwater best management practices (BMPs) consistent with the MS4 general permit requirements. Especially since current lead concentrations in the stormwater runoff are 5 to 25 times elevated over the chronic aquatic life criterion applicable to the Bitterroot River.

BMP effectiveness values reported from the International Storm Water BMP Database (Geosyntec Consultants, Inc. and Wright Water Engineers, Inc., 2012) are used as the basis for setting the WLA_{MS4}. The database provides summary statistics for reduction efficiencies from a variety of BMPs. Metals studied include arsenic, cadmium, chromium, copper, iron, lead, nickel, and zinc, both dissolved and total fractions. Studied BMPs include: grass strips, bioretention, bioswales, detention basins, manufactured devices, media filters, porous pavement, and retention ponds, among others. The International Storm Water BMP Database summarizes BMP effectiveness studies by evaluating the 25^{th}, median, and 75^{th} percentile concentrations of influent and effluent. To set this allocation, DEQ used the median influent and effluent concentrations from the BMP Database, and established an average percent reduction in lead concentrations of 54%. Although runoff from commercial source areas contains higher concentrations of lead, because a larger extent of the MS4 contributing area is classified residential, both source areas contribute a similar load to the Bitterroot River. Since loading contributions are comparable, percent reductions are not area weighted by commercial or residential categories as DEQ has done in some previous TMDLs (Montana Department of Environmental Quality, 2014a). The wasteload allocation to the Missoula MS4 is a 54% reduction in lead loads. This equates to a 0.08 lbs/day based on the daily load estimates provided above. The WLA is not intended to add concentration or load limits to the permit. Consistent with EPA guidance (U.S. Environmental Protection Agency, 2002), DEQ assumes the WLA will be met by adhering to the permit requirements and reducing either the lead concentration or the discharge volume, or both. As identified in the permit, monitoring data should continue to be collected and evaluated to assess BMP performance and help identify whether and where additional BMP implementation may be necessary. DEQ chose to set the MS4 allocation according to the process outlined above instead of setting the allocation as a product of the point source's discharge and the target concentration in a manner consistent with most point sources in Montana (see **Section 4.4**), because, as shown through the analysis described in **Section 6.5.1**, the loading contribution from the Missoula MS4 is negligible compared to the river's total allowable load (0.6%). Additionally, practice has shown that requiring and supporting the implementation of stormwater management plans is a more effective way of achieving WLA compliance for MS4s than establishing strict daily load limits due to the unique nature of MS4 point sources.

Lolo Wastewater Treatment Plant (WWTP)

The Lolo WWTP is a minor publicly owned treatment works facility with a MPDES permit (MT0020168) to discharge treated wastewater directly into the Bitterroot River between Lolo Creek and Miller Creek. The permit does not contain effluent limits for lead. As discussed in **Section 6.5.1**, the Lolo WWTP contributes an estimated 0.0009 lbs/day of lead to the Bitterroot River during high flow conditions when lead impairment is of a concern. This load represents 0.004% of the total allowable load (TMDL) for the river. Because of its extremely small influence on the lead concentration and load in the Bitterroot River, the Lolo WWTP is considered an insignificant source of lead and will not be required to reduce the lead concentration in its effluent for this specific TMDL. An example WLA is provided below using the existing average effluent concentration and design flow to show how the load from the WWTP fits into the TMDL and that the allowable load is greater than zero. However, because no reduction is necessary and the WWTP will still be an insignificant source even if its average effluent concentration is greater than 0.7 µg/L, the example WLA should not be incorporated into a permit limit. The intent of this WLA will be met by following all permit requirements, including monitoring. Quarterly monitoring is required for the next permit cycle; if the annual average concentration is less than 1.4 µg/L (twice the current average but still not measurably increasing the concentration in the river), loading from the Lolo WWTP meets the assumptions of the WLA, and subsequent monitoring for compliance with the intent of this WLA may be conducted once per permit cycle. This 1.4 µg/L is similar to concentration-based effluent limits for comparable domestic wastewater facilities recently established in TMDLs for the Clark Fork River (Montana Department of Environmental Quality, 2014a).

If the average effluent concentration exceeds 1.4 ug/L, a reasonable potential analysis should be conducted to determine if a permit limit is needed in the future. However, additional data from the Bitterroot River, especially directly upstream of the WWTP outfall, should be collected prior to performing a reasonable potential analysis. Particularly since the source assessment performed for this TMDL project indicates that lead exceedances in the Bitterroot River may be linked to the 2000 forest fires and that lead concentrations within the river could be on a downward trend leading toward potential non-impairment conditions within the next decade without any operation changes/upgrades to this facility. Supporting this theory, DEQ's most recent lead samples on this segment of the Bitterroot River from 2012 were all at or below detection levels and the most recent chronic aquatic life exceedance occurred five years ago in 2009.

The example WLA for the Lolo WWTP can be calculated using the following equation:

$$WLA_{LoloWWTP} = \text{WWTP design flow (cfs)} \times \text{existing concentration (µg/L)} \times \text{conversion factor}$$

- WWTP design flow = 0.53 cfs
- existing concentration = 0.7 µg/L
- conversion factor = 0.0054

$$WLA_{LoloWWTP} = 0.53 \text{ cfs} \times 0.7 \text{ µg/L} \times 0.0054 = 0.002 \text{ lbs/day}$$

Nonpoint Sources

A number of nonpoint sources were discussed in **Section 6.5.1**, including sediment in runoff from disturbed public and private forest land, seepage from landfills and/or underground storage tanks, abandoned mines, the use of lead fishing weights, and the use of lead shot on shooting ranges. Based on the source assessment performed for this TMDL, each one of these sources individually is considered minor and not a cause for impairment. A composite allocation for all nonpoint sources within the River's lower segment basin was calculated by taking the difference between the TMDL and the other source allocations as follows:

$$LA_{NPS} = TMDL - (WLA_{MS4} + WLA_{LoloWWTP} + LA_{UW} + LA_{Nat})$$

High Flow:
$LA_{NPS} = 27.00 - (0.08 + 0.002 + 23.49 + 1.95) = 1.48$

Low Flow:
$LA_{NPS} = 9.23 - (0.08 + 0.002 + 8.03 + 0.16) = 0.96$

Allocations Summary

Tables 6-9 and **6-10** summarize the reductions, by source category, required to meet the high and low flow lead allocations for the example Bitterroot River TMDL. The TMDL under different flow and water hardness scenarios is defined by the equation provided in **Section 6.6.1**.The available monitoring dataset suggests that targets are met and no loading reductions are required during low flow conditions. During high flow, a total loading reduction as high as 77% is necessary. The majority of loading reduction will come from the basin's composite nonpoint source allocation (LA_{NPS}), however, small reductions are also expected from the Missoula MS4 (WLA_{MS4}) through the implementation of their stormwater management plan and MPDES permit. Also, the WLA_{MS4} loads listed in **Table 6-9** and **6-10** assume a precipitation event greater than 0.25 inches occurred. For other days, which is most of the year, the MS4 does not discharge to the Bitterroot River and the load is effectively zero. Note, these percent reduction examples are based on the highest observed lead concentrations and represent the largest reductions that would be necessary to meet water quality standards. At other times, as shown in the low flow TMDL example in **Table 6-10**, no reduction is necessary because the river is already meeting lead target as witnessed in 57 of the 68 water quality samples.

Table 6-9. High Flow Bitterroot River Example Lead TMDL, Percent Reductions, and Allocations

Allocation	Source Category	Current Load (lbs/day)	Percent Reduction	Allocation (lbs/day)	Rationale/Assumptions
Load Allocation	Upper Watershed (LA_{UW})	23.49	0%	23.49	The middle Bitterroot River segment (MT76H001_020) is not impaired by lead thus DEQ assumes the upper watershed is contributing lead at the target concentration and no reduction is required.
	Natural Background (LA_{NAT})	1.95	0%	1.95	No reduction possible from this source category.
	Composite Nonpoint Source (LA_{NPS})	92.88	98%	1.48	Composite allocation to all other nonpoint sources within the lower Bitterroot watershed. Source assessment was unable to identify the chief cause of impairment however most of reduction required to meet the TMDL will come from this source category which will be refined through adaptive management processes in the future.
Wasteload Allocation	Missoula MS4 (WLA_{MS4})	0.18	54%	0.08	Concentrations in runoff currently exceed the target. Reduction based on what is achievable according to International Storm Water BMP database.
	Lolo WWTP ($WLA_{LoloWWTP}$)	0.002	0%	0.002	No reduction required at this time. Negligible source with no measureable impact to river water quality.
TMDL	All Sources	118.5	77%	27.00	

Table 6-10. Low Flow Bitterroot River Example Lead TMDL, Percent Reductions, and Allocations

Allocation	Source Category	Current Load (lbs/day)	Percent Reduction	Allocation (lbs/day)	Rationale/Assumptions
Load Allocation	Upper Watershed (LA_{UW})	7.05	0%	8.03	The middle Bitterroot River segment (MT76H001_020) is not impaired by lead thus DEQ assumes the upper watershed is contributing lead at the target concentration and no reduction is required.
	Natural Background (LA_{NAT})	0.16	0%	0.16	No reduction possible from this source category.
	Composite Nonpoint Source (LA_{NPS})	0.71	0%	0.96	Composite allocation to all other nonpoint sources within the lower Bitterroot watershed. Source assessment was unable to identify the chief cause of impairment however most of reduction required to meet the TMDL will come from this source category which will be refined through adaptive management processes in the future.
Wasteload Allocation	Missoula MS4 (WLA_{MS4})	0.18	54%	0.08	Concentrations in runoff currently exceed the target. Reduction based on what is achievable according to International Storm Water BMP database.
	Lolo WWTP ($WLA_{LoloWWTP}$)	0.002	0%	0.002	No reduction required at this time. Negligible source with no measureable impact to river water quality.
TMDL	All Sources	8.1	0%	9.23	

6.6.2.2 Lick Creek (MT76H004_170)

Allocations for Lick Creek include a load allocation to natural background sources (LA_{Nat}) and a load allocation to nonpoint sources (LA_{NPS}). The aluminum TMDL for Lick Creek is expressed by the following formula:

$$TMDL_{Lick} = LA_{Nat} + LA_{NPS}$$

A wasteload allocation is not given since there are no known mining sources and no MPDES permitted point sources draining to Lick Creek.

Natural Background

Naturally occurring sources are provided a load allocation in pounds per day based on naturally occurring metals concentrations and streamflow. As defined in ARM 17.30.602, naturally occurring sources include metals loading from non-human (natural background) sources as well as ”those sources from developed areas where all reasonable land, soil and water conservation practices have been applied.” The underlying assumption is that natural background sources alone would not result in metals target exceedances in the water column or streambed sediments. If future monitoring proves this to be incorrect, these TMDLs may need to be revised in accordance with the adaptive management strategy outlined in **Section 6.8**.

Due to a low degree of confidence in identifying reference monitoring sites not influenced by human activity in the Lick Creek watershed, the naturally-occurring aluminum concentration is derived by reviewing three information sources. First, because Montana's aluminum aquatic life criteria are written for the dissolved sample fraction, groundwater samples (also in the dissolved fraction) can be directly compared to criteria and may be used to distinguish where groundwater is elevated from potentially natural sources such as geology. One groundwater sample within the watershed is available. MBMG sampled groundwater near the mouth of Lick Creek at a site named "Lick Creek Campground." The sample did not detect aluminum (<30 µg/L) suggesting groundwater is not naturally high in aluminum. Second, summary statistics were run on a dataset downloaded from the national Water Quality Portal (U.S. Geological Survey and U.S. Environmental Protection Agency, 2014) that included all surface water samples of dissolved aluminum collected since 2004 in the Bitterroot watershed hydrologic unit (17010205). Selecting the 25^{th} percentile of a larger, non-reference dataset to represent natural background, is a technique that has been used in previous Montana TMDLs when reference sites are not available (Montana Department of Environmental Quality and U.S. Environmental Protection Agency, 2013). Using detection limits for non-detect samples in calculations, the 25^{th} percentile of the dataset is 30 µg/L. Finally, the third source of information used to derive a natural aluminum concentration was the surface water dataset collected from a nearby stream, Tin Cup Creek, where DEQ's Water Quality Standards Section has established a site as part of its statewide network of reference sites. Tin Cup Creek is located less than four miles south of Lick Creek, overlays similar geology, and also flows west out of the Bitterroot Mountains. DEQ sampling results of Tin Cup Creek from 2012 and 2013 ranged from 19 to 60 µg/L with a 25^{th} percentile of 27 µg/L. These three information sources indicate that 30 µg/L is a reasonable approximation of natural background aluminum concentrations in Lick Creek. This estimation also agrees with the typical background concentrations of 1 to 50 ug/L cited by the World Health Organization (World Health Organization, 2003a) for waters with near-neutral pH.

The example LAs for natural background were calculated using the example high and low flows from **Table 6-8** the background concentration of 30 µg/L, and the conversion factor of 0.0054 as follows:

High Flow:
LA_{Nat} = 12.92 cfs x 30 µg/L x 0.0054 = 2.09 lbs/day

Low Flow:
LA_{Nat} = 2.25 cfs x 30 µg/L x 0.0054 = 0.36 lbs/day

Nonpoint Sources
A number of nonpoint sources were discussed in **Section 6.5.2**, including aluminum in livestock feed and sediment-bound aluminum in runoff from forestry, unpaved roads, off-road vehicle use, agriculture, and other disturbed areas. Each one of these sources is considered minor, and no evidence exists that a single nonpoint source is a cause for impairment. A composite allocation for all nonpoint sources was calculated by taking the difference between the TMDL and the natural background load as follows:

$$LA_{NPS} = TMDL – LA_{Nat}$$

High Flow:
LA_{NPS} = 6.07 – 2.09 = 3.98 lbs/day

Low Flow:

LA_{NPS} = 1.06 – 0.36 = 0.70 lbs/day

Allocations Summary

Tables 6-11 and **6-12** summarize the reductions, by source category, required to meet the high and low flow aluminum allocations for the example Lick Creek TMDL. The TMDL under different flow and water hardness scenarios is defined by the equation provided in **Section 6.6.1**. Reductions are required during both flow conditions and range as high as 88%. Because no additional reductions are expected from the natural background allocation (LA_{Nat}) based on its definition, actual reductions in human-caused nonpoint source loading increase to 92% during high flow conditions. Note, these percent reduction examples are based on the highest observed aluminum concentrations and represent the largest reductions that would be necessary to meet water quality standards. At other times, no reduction is necessary because the creek is already meeting aluminum targets as witnessed in four of the ten water quality samples.

Table 6-11. High Flow Lick Creek Example Aluminum TMDL, Percent Reductions, and Allocations

Allocation	Source Category	Current Load (lbs/day)	Percent Reduction	Allocation (lbs/day)	Rationale/Assumptions
Load Allocation	Natural Background (LA_{NAT})	2.09	0%	2.09	No reduction possible from this source category.
	Composite Nonpoint Source (LA_{NPS})	52.05	92%	3.98	Composite allocation to all other nonpoint sources within the Lick Creek watershed. Source assessment was unable to identify the chief cause of impairment however most of reduction required to meet the TMDL will come from this source category which will be refined through adaptive management processes in the future.
TMDL	All Sources	54.14	88%	6.07	

Table 6-12. Low Flow Lick Creek Example Aluminum TMDL, Percent Reductions, and Allocations

Allocation	Source Category	Current Load (lbs/day)	Percent Reduction	Allocation (lbs/day)	Rationale/Assumptions
Load Allocation	Natural Background (LA_{NAT})	0.36	0%	0.36	No reduction possible from this source category.
	Composite Nonpoint Source (LA_{NPS})	3.25	78%	0.7	Composite allocation to all other nonpoint sources within the Lick Creek watershed. Source assessment was unable to identify the chief cause of impairment however most of reduction required to meet the TMDL will come from this source category which will be refined through adaptive management processes in the future.
TMDL	All Sources	3.61	71%	1.06	

6.7 Seasonality and Margin of Safety

Streamflow, water hardness, and climate vary seasonally. All TMDL documents must consider the effects of this variability on water quality impairment conditions, maximum allowable pollutant loads in a stream (TMDLs), and loading allocations. TMDL development must also incorporate a margin of safety into the allocation process to account for uncertainties in pollutant sources and other watershed conditions, and ensure (to the degree practicable) that the TMDL components and requirements are sufficiently protective of water quality and designated uses. This section describes the considerations of seasonality and a margin of safety (MOS) in the Bitterroot watershed metals TMDL development process.

6.7.1 Seasonality

Seasonality addresses the need to ensure year round designated use support. Seasonality is considered for assessing loading conditions and for developing water quality targets, TMDLs, and allocation schemes. For metals TMDLs, seasonality is important because metals loading pathways and water hardness change from high to low flow conditions. During high flows, loading associated with overland flow and erosion of metals-contaminated soils and mine wastes tend to be the major cause of elevated metals concentrations. During low flow, groundwater transport and/or adit discharges are often found to be the chief source of elevated metals concentrations. Hardness tends to be lower during higher flow conditions, which leads to more stringent water quality standards for hardness-dependent metals during the runoff season. Seasonality is addressed in this document as follows:

- Metals concentrations and loading conditions are evaluated for both high flow and low flow conditions. DEQ’s assessment method requires a combination of both high and low flow sampling for target evaluation since abandoned mines and other metals sources can lead to elevated metals loading during high and/or low flow conditions.
- Metals TMDLs incorporate streamflow as part of the TMDL equation.
- Metals concentration targets apply year round, with monitoring criteria for target attainment developed to address seasonal water quality extremes associated with loading and hardness variations.
- A sediment chemistry target is applied as a supplemental indicator to help capture impacts from episodic metals loading events that could be attributed to high flow seasonal runoff conditions.
- Example targets, TMDLs and load reduction needs are developed for high and low flow conditions. The TMDL equation incorporates all potential flow conditions that may occur during any season.

6.7.2 Margin of Safety

The margin of safety is to ensure that TMDLs and allocations are sufficient to sustain conditions that will support designated uses. All metals TMDLs incorporate an implicit MOS in several ways, using conservative assumptions throughout the TMDL development process, as summarized below:

- DEQ’s assessment process includes a mix of high and low flow sampling since metals sources can lead to elevated metals loading during high and/or low flow stream conditions. The seasonality considerations help identify the low range of hardness values and thus the lower range of applicable TMDL values shown within the TMDL curves and captured within the example TMDLs.
- Target attainment, refinement of load allocations, and, in some cases, impairment validations and TMDL-development decisions are all based on an adaptive management approach that relies on future monitoring and assessment for updating planning and implementation efforts.

- Although a 10% exceedance rate is allowed for chronic and acute based aquatic life targets, the TMDLs are set so the lowest applicable target is satisfied 100% of the time. This focuses remediation and restoration efforts toward 100% compliance with all targets, thereby providing a margin of safety for the majority of conditions where the most protective (lowest) target value is linked to the numeric aquatic life standard. As part of this, the existing water quality conditions and needed load reductions are based on the highest measured value for a given flow conditions in order to consistently achieve the TMDL.
- The monitoring results used to estimate existing water quality conditions are instantaneous measurement used to estimate a daily load, whereas chronic aquatic life standards are based on average conditions over a 96-hour period. This provides a margin of safety since a four-day loading limit could potentially allow higher daily loads in practice.
- The lowest or most stringent numeric water quality standard was used for TMDL target and impairment determination for all waterbody – pollutant combinations. This ensures protection of all designated beneficial uses.
- Sediment metals concentration criteria were used as a supplemental indicator target. This helps ensure that episodic loading events were not missed as part of the sampling and assessment activity.
- The TMDLs are based on numeric water quality standards developed at the national level via EPA and incorporate a margin of safety necessary for the protection of human health and aquatic life.

6.8 Uncertainty and Adaptive Management

The environmental studies required for TMDL development include inherent uncertainties: accuracy of field and laboratory data, for example. Data concerns are managed by DEQ's data quality objective (DQO) process. The use of DQOs ensures that the data is of known (and acceptable) quality. The DQO process develops criteria for data performance and acceptance that clarify study intent, define the appropriate type of data, and establish minimum standards for the quality and quantity of data.

The accuracy of source assessments and loading analyses is another source of uncertainty. An adaptive management approach that revisits, confirms, or updates loading assumptions is vital to maintaining stakeholder confidence and participation in water quality improvement. Adaptive management uses updated monitoring results to refine loading analysis, to further customize monitoring strategies and to develop a better understanding of impairment conditions and the processes that affect impairment. Adaptive management recognizes the dynamic nature of pollutant loading and water quality response to remediation.

Adaptive management also allows for continual feedback on the progress of restoration and the status of beneficial uses. Additional monitoring and resulting refinements to loading can improve the ability to measure and achieve success. A remediation and monitoring framework is closely linked to the adaptive management process, and is addressed in **Section 10.0**.

The metals TMDLs developed for the Bitterroot TMDL Project Area are based on future attainment of water quality standards. In order to achieve this, all significant sources of metals loading must be addressed via all reasonable land, soil, and water conservation practices. DEQ recognizes however, that in spite of all reasonable efforts, this may not be possible due to natural background conditions and/or the potential presence of unalterable human-caused sources that cannot be fully addressed via reasonable remediation approaches. For this reason, an adaptive management approach is adopted for all metals targets described within this document. Under this adaptive management approach, all metals impairments that required TMDLs will ultimately fall into one of the four categories identified below:

- Restoration achieves the metal pollutant targets and all beneficial uses are supported.
- Targets are not attained because of insufficient controls; therefore, impairment remains and additional remedies are needed.
- Targets are not attained after all reasonable BMPs and applicable abandoned mine remediation activities are applied. Under these circumstances, site-specific standards may be necessary.
- Targets are unattainable due to naturally-occurring metals sources. Under this scenario, site-specific water quality standards and/or the reclassification of the waterbody may be necessary. This would then lead to a new target (and TMDL) for the pollutant(s) of concern, and the new target would reflect the background condition.

As discussed in **Section 6.3**, monitoring following the 2000 wildfires indicated that runoff from burnt locations was a source of lead to the Bitterroot River. Sediment bound lead from the wildfires may still exist within streambed sediments and result in elevated concentrations following resuspension during high flows. If continued monitoring demonstrates no further exceedances, then the recent lead exceedances may have been a result of wildfires. The possibility of this effect should be noted during the adaptive management process.

If further investigation identifies abandoned mines as sources of lead, the Abandoned Mines Section of DEQ's Remediation Division will lead abandoned mine restoration projects funded by provisions of the Surface Mine Reclamation and Control Act of 1977. DEQ's Federal Superfund Bureau (also in the Remediation Division) will provide technical and management assistance to EPA for remedial investigations and cleanup actions at national priorities list mine and landfill sites in federal-lead status.

Monitoring and restoration conducted by other parties (e.g. USFS, Bureau of Land Management (BLM), the Montana Department of Natural Resources and Conservation's Trust Lands Management Division, The Nature Conservancy) should be incorporated into the target attainment and review process as well. Cooperation among agency land managers in the adaptive management process for metals TMDLs will help identify further cleanup and load reduction needs, evaluate monitoring results, and identify water quality trends.

7.0 Temperature TMDL Components

This portion of the document focuses on temperature as an identified cause of water quality impairment in the Bitterroot Project Area. It describes: (1) the mechanisms by which temperature affects beneficial uses of streams; (2) the stream segments of concern; (3) information sources used for temperature total maximum daily load (TMDL) development; (4) temperature target development; (5) assessment of sources contributing to excess thermal loading; (6) the temperature TMDL and allocations; (7) seasonality and margin of safety; and (8) uncertainty and adaptive management.

7.1 Temperature (Thermal) Effects on Beneficial Uses

Human influences that reduce stream shade, increase stream channel width, add heated water, or decrease the capacity of the stream to buffer incoming solar radiation all increase stream temperatures. Warmer temperatures can negatively affect aquatic life that depends upon cool water for survival. Coldwater fish species are more stressed in warmer water temperatures, which increases metabolism and reduces the amount of available oxygen in the water. Coldwater fish and other aquatic life may feed less frequently and use more energy to survive in thermal conditions above their tolerance range, which can result in fish kills. Also, elevated temperatures can boost the ability of non-native fish to outcompete native fish if the latter are less able to adapt to warmer water conditions (Bear et al., 2007). Although the TMDL will address increased summer temperatures as the most likely to cause detrimental effects on fish and aquatic life, human influences on stream temperature, such as those that reduce shade, can also lead to lower minimum temperatures during the winter (Hewlett and Fortson, 1982). Lower winter temperatures can lead to the formation of anchor and frazil ice which can harm aquatic life by causing changes in movement patterns (Brown, 1999; Jakober et al., 1998), reducing available habitat, and inducing physiological stress (Brown et al., 1993). Addressing the issues associated with increased summer maximum temperatures will also address these potential winter problems. Assessing thermal effects upon a beneficial use is an important initial consideration when interpreting Montana's water quality standard (**Appendix B**) and subsequently developing temperature TMDLs.

7.2 Stream Segments of Concern

One waterbody segment in the Bitterroot Project Area is identified as impaired by temperature in Montana's 2012 Integrated Report (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012b): Mill Creek (**Appendix A**, **Figure A-8**).To help put sampling data into perspective and understand how elevated stream temperatures may affect aquatic life, information on fish presence in these waterbodies and temperature preferences for the most sensitive species are described below.

7.2.1 Fish Presence in Mill Creek

Based on a query of the Montana Fisheries Information System (MFISH), Mill Creek is inhabited by brook trout, brown trout, bull trout, longnose dace, mountain whitefish, slimy sculpin, rainbow trout, and westslope cutthroat trout (Montana Department of Fish, Wildlife and Parks, 2014). Mill Creek is not within a Nodal bull trout area but most of the stream is a Core bull trout area (Montana Department of Fish, Wildlife and Parks, 2014). According to the Montana Fish, Wildlife, and Parks fisheries resource value ratings, Mill Creek is considered "Outstanding" (rating score 1) (Montana Department of Fish, Wildlife and Parks, 2014).

7.2.2 Temperature Levels of Concern

Special temperature considerations are warranted for the westslope cutthroat trout, which are identified in Montana as species of concern, and for the bull trout, which are classified as threatened by the US Fish and Wildlife Service. Research by Bear et al. (2007) found that westslope cutthroat maximum growth occurs around 56.5°F, with an optimum growth range (based on 95% confidence intervals) from 50.5–62.6°F. The ultimate upper incipient lethal temperature (UUILT) is the temperature considered to be survivable by 50% of the population over a specified time period. Bear et al. (2007) found the 60-day UUILT for westslope cutthroat trout to be 67.3°F and the 7-day UUILT to be 75.4°F. Considering a higher level of survival, the lethal temperature dose that will kill 10% (LD10) of the population in a 24-hour period for westslope cutthroat is 73.0°F (Lines and Graham, 1988).

Bull trout are listed as threatened under the U.S. Endangered Species Act. UUILT for bull trout is 68.5°F (Selong et al., 2001). The LD10 for bull trout is 74°F (McCullough and Spalding, 2002). Bull trout have maximum growth near 59.5°F (McCullough and Spalding, 2002), with an optimum growth range of 51.6°F to 59.7°F (Selong et al., 2001).

7.3 Information Sources and Data Collection

As discussed in **Appendix B** and **Section 7.4.1**, Montana defines temperature impairment as occurring when human sources cause a certain degree of change over the water temperature that occurs as a result of natural sources and human sources that are implementing all reasonable land, soil, and water conservation practices. Because interpreting the standard is more complex than just comparing measured temperatures to the temperature levels of concern discussed above, a QUAL2K water quality model was needed to determine if human sources are causing the allowable temperature change to be exceeded in Mill Creek. Model details for Mill Creek are presented in **Attachment A**, but the model summary and outcome is provided in **Section 7.5**, **Source Assessment**.

The following information sources were searched and/or used to set up the QUAL2K model and assist with temperature TMDL development.

7.3.1 DEQ Assessment Files

Department of Environmental Quality (DEQ) maintains assessment files that provide a summary of available water quality and other existing condition information, along with a justification for impairment determinations.

7.3.2 Temperature Related Data Collection

In summer 2013, Tetra Tech (under contract with Environmental Protection Agency (EPA)) and DEQ collected temperature data, along with measurements of streamflow, riparian shade, and channel geometry from Mill Creek. This information is collectively used within the QUAL2K models to evaluate impairment and the potential for improvement associated with the implementation of all reasonable land, soil, and water conservation practices. These data are presented and described in detail in **Attachment A**. Monitoring locations are shown in **Figure 7-1**.

Figure 7-1. Temperature data logger sampling sites on Mill Creek and nearby weather stations.

7.3.3 Climate Data

Climate data, including air temperature, dew point temperature, wind speed, and cloud cover, are major inputs to the QUAL2K model and are also drivers for stream temperature. Two weather stations are near the Mill Creek watershed (**Figure 7-1**). Climatic data inputs, including hourly air temperature, were obtained from the Smith Creek Remote Automatic Weather Stations (RAWS; 242912) (**Figure 7-1**).

7.3.4 Water Usage Data

Irrigation diversion locations and flow rates for the 2014 irrigation season were obtained from the Mill Creek Irrigation District (Tollefson, Jordan personal communications, 2014[6]). This information was necessary because streamflow is an important input for the QUAL2K model and irrigation withdrawals have the potential to influence stream temperatures.

[6] Personal communication between Jordan Tollefson, Montana Department of Environmental Quality and Sandy Schlotterbeck and David Allen, Mill Creek Irrigation District. February 5, 10 and 13, 2014.

7.4 Target Development

The following section describes 1) the framework for interpreting Montana's temperature standard; 2) the selection of target parameters and values used for TMDL development; and 3) a summary of the temperature target values for Mill Creek.

7.4.1 Framework for Interpreting Montana's Temperature Standard

Montana's water quality standard for temperature is narrative in that it specifies a maximum allowable increase above the naturally occurring temperature to protect fish and aquatic life. Under Montana water quality law, naturally occurring temperatures incorporate natural sources and human sources that are applying all reasonable land, soil, and water conservation practices. Naturally occurring temperatures can be estimated for a given set of conditions using QUAL2K or other modeling approaches, but because water temperature changes daily and seasonally, no single temperature value can be identified to represent standards attainment. Therefore, in addition to evaluating if human sources are causing the allowable temperature change to be exceeded, a suite of temperature TMDL targets were developed to translate the narrative temperature standard into measurable parameters that collectively represent attainment of applicable water quality standards at all times. The goal is to set the target values at levels that occur under naturally occurring conditions but are conservatively selected to incorporate an implicit margin of safety that helps account for uncertainty and natural variability. The target values are protective of the use most sensitive to elevated temperatures, aquatic life; as such, the targets are protective of all designated uses for the applicable waterbody segments.

A QUAL2K model was used for Mill Creek to estimate the extent of human influence on temperature by evaluating the temperature change between existing conditions and naturally occurring conditions. The models used the data described in **Section 7.3** to simulate existing conditions, and then the models were re-run with riparian shade and water use altered to reflect naturally occurring conditions. If the modeled temperature change between the two scenarios (i.e., existing and naturally occurring) is greater than allowed by the water quality standard (i.e., 0.5-1.0°F, depending on the naturally occurring temperature), this verifies the existing temperature impairment. This section discusses whether the model outcome supports the existing impairment listing, and model scenario details are presented in **Section 7.5**, **Source Assessment** and **Attachment A**.

7.4.2 Temperature Target Parameters and Values

The primary temperature target is the allowable human-caused temperature change (i.e., 0.5-1.0°F, depending on the naturally occurring temperature), and the other targets are those parameters that influence temperature and can be linked to human causes. The other targets are riparian shade, channel geometry, and improved streamflow conditions. All targets are described in more detail below.

7.4.2.1 Allowable Human-Caused Temperature Change

The target for allowable human-caused temperature change links directly to the numeric portion of Montana's temperature standard for B-1 streams (ARM 17.30.623(e)): When the naturally occurring temperature is less than 66°F, the maximum allowable increase is 1°F. Within the naturally occurring temperature range of 66–66.5°F, the allowable increase cannot exceed 67°F. If the naturally occurring temperature is greater than 66.5°F, the maximum allowable increase is 0.5°F. As stated above, naturally occurring temperatures incorporate natural sources, yet also include human sources that are applying all reasonable land, soil, and water conservation practices.

7.4.2.2 Riparian Shade

Increased shading from riparian vegetation reduces sunlight hitting the stream and, thus, reduces the heat load to the stream. Riparian vegetation also reduces near-stream wind speed and traps air against the water surface, which reduces heat exchange with the atmosphere (Poole and Berman, 2001). In addition, lack of established riparian areas can lead to bank instability, which can result in an overwidened channel.

A reference-based approach was used to establish the shade targets using areas along Mill Creek where riparian vegetation and associated shade where at or near potential, and recent anthropogenic influences were minimal. Between river mile 9.5 and river mile 6.5, Mill Creek flows through an area transitional from the mountains (dominated by coniferous forest) down to the valley. Much of this reach is dominated by mixed coniferous/deciduous forest with some encroachment by residential and agricultural land uses. Site MC-T3 (a forested site dominated by mixed coniferous/deciduous vegetation) was considered at potential based on site reconnaissance and is used to define reference shade for this reach. Average daily shade at Site MC-T3 is, on average, approximately 20 percent greater than areas upstream and downstream within this reach (**Figure 7-2**).

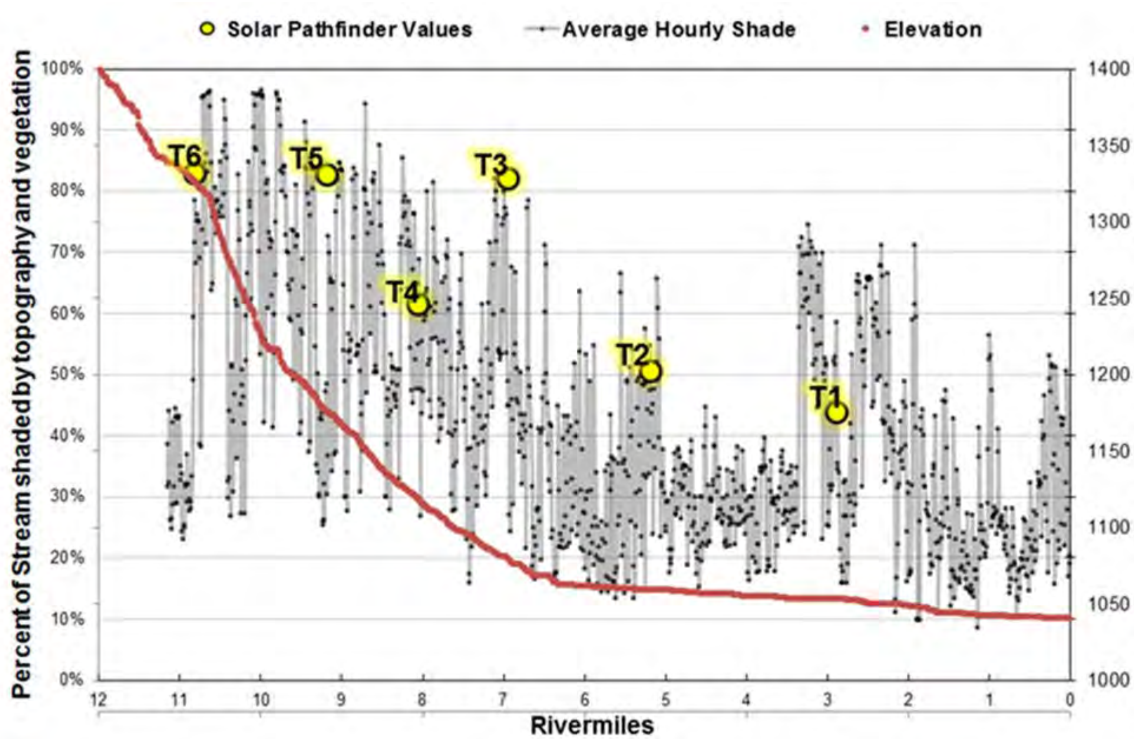


Figure 7-2. Shading and elevation along Mill Creek.

The downstream reach (from approximately river mile 6.5 to the mouth) is relatively low gradient and flows through the Bitterroot Valley bottom. Irrigated agriculture mixed with low density residential land uses predominate. Much of this reach is not meeting its shade potential due to encroachment by these land uses. However, based on site reconnaissance in 2013, the vegetation at site MC-T2 is at potential; this site is used as a reference condition for this reach. Vegetation in the vicinity of site MC-T2 consists of a 50 to 100 foot buffer of shrubs and average daily effective shade is approximately 50%, compared to approximately 30% in much of the rest of this reach.

Based on existing vegetation in the watershed and what is known of historical conditions, the effective shade provided by these reference conditions was determined to be a reasonable target. Effective shade is the result of topography and vegetative height and density, so the target shade condition could be achieved by a large combination of vegetation types and densities. Additionally, the effective shade potential at any given location may be lower or higher than the target depending on natural factors such as fire history, soil, topography, and aspect but also because of human alterations to the near-stream landscape including roads and structural bank armoring that may not feasibly be modified or relocated. The target is provided as a quantitative guide for meeting the standard but since it is intended to represent all reasonable land, soil, and water conservation practices, if those are being implemented, then Mill Creek will be meeting the riparian shade target. The rationale for target selection is further described in **Section 7.4.4.1** in the discussion of existing conditions as compared with the target.

7.4.2.3 Instream Flow (Water Use)

Because larger volumes of water take longer to heat up during the day, the ability of a stream to buffer incoming solar radiation is reduced as instream water volume decreases. In other words, a channel with little water will heat up faster than an identical channel full of water, even if they have identical shading and are exposed to the same daily air temperatures.

The proposed target for instream flow (water use) is the increased instream flow that can be achieved via a 15% reduction in flow diverted for irrigation purposes based on improvements in irrigation water management and irrigation system and delivery efficiencies during the summer (June through September). Per Montana's water quality law, TMDL development cannot be construed to divest, impair, or diminish any water right recognized pursuant to Title 85 (Montana Code Annotated (MCA) §75-5-705). Therefore, any voluntary water savings and subsequent instream flow augmentation must be done in a way that protects water rights. The 15% water savings could be achieved through best management practices including delivery system upgrades, irrigation scheduling, and application management (Waskom, 1994).

7.4.3 Target Values Summary

The allowable human-caused temperature change is the primary target that must be achieved to meet the standard. Alternatively, compliance with the temperature standard can be attained by meeting the three temperature-influencing targets (i.e., riparian shade, width/depth ratio, and instream flows). In this approach, if all reasonable land, soil, and water conservation practices are installed or practiced, water quality standards will be met. **Table 7-1** summarizes the temperatures targets for Mill Creek.

Table 7-1. Temperature Targets for Mill Creek

Target Parameter	Target Value
Primary Target	
Allowable Human-Caused Temperature Change	If the naturally occurring temperature is less than 66°F, the maximum allowable increase is 1°F. Within the naturally occurring temperature range of 66–66.5°F, the allowable increase cannot exceed 67°F. If the naturally occurring temperature is greater than 66.5°F, the maximum allowable increase is 0.5°F.
Temperature-Influencing Targets: Meeting both will meet the primary target	
Riparian Health - Shade	Internally derived reference shade
Instream Flows (Water Use)	15% reduction of irrigation withdrawals due to improvements in irrigation efficiency during the summer (June through September)

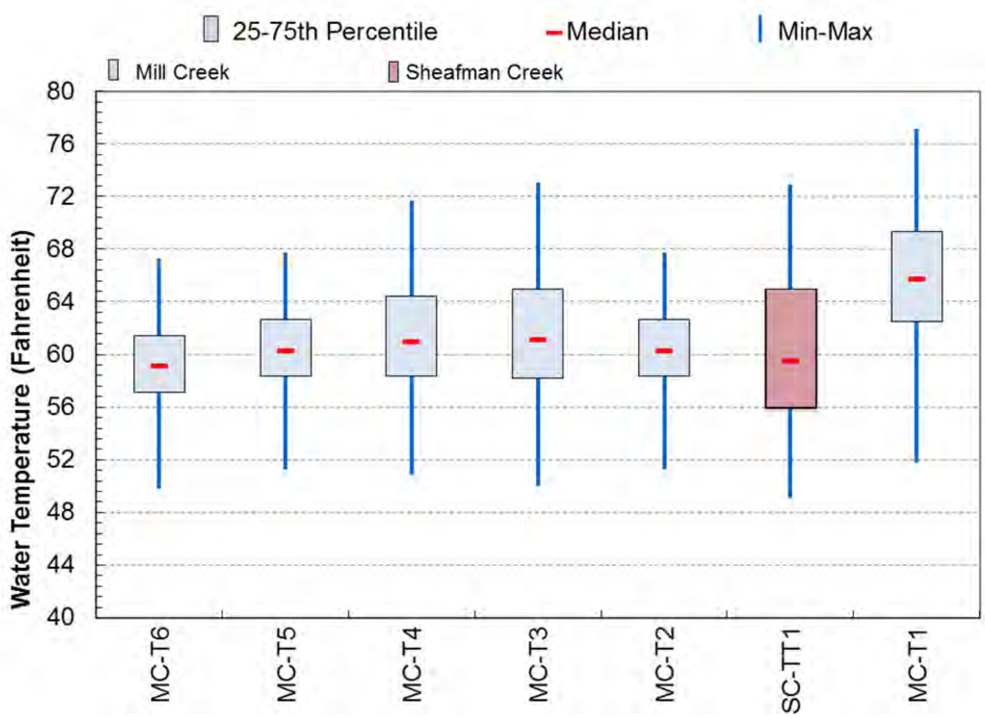
7.4.4 Existing Conditions and Comparison to Targets

This section includes a comparison of existing data with water quality targets, along with a TMDL development determination for Mill Creek. QUAL2K model results will be compared to the allowable human-caused temperature change to determine if the target is being exceeded, but most model details will be presented in **Section 7.5**, **Source Assessment**.

Mill Creek (MT76H004_040) was initially listed for temperature impairment in 2010. The assessment file identified previous temperature studies, with continuously recording loggers; these studies concluded that (1) instream daily maximum temperatures increase considerably and (2) Mill Creek was chronically dewatered (Montana Department of Environmental Quality, 2014d). It was also noted that overgrazing, physical modifications, road construction, and residential development were impacting the stream and riparian zone (Montana Department of Environmental Quality, 2014d).

7.4.4.1 Existing Stream Temperatures

To help evaluate the extent and implications of impairment it is useful to evaluate the degree to which existing temperatures may harm fish or other aquatic life. Westslope cutthroat trout are used herein as an indicator species for purposes of this discussion. Observed temperatures were commonly outside the optimal growth range for westslope cutthroat trout and maximum daily temperatures exceeded 73°F, which is the LD-10, at logger MC-T1 (**Figure 7-3**). Measured temperatures were warmest for the longest period of time near the mouth at MC-T1. Temperatures within the lethal range discussed in **Section 7.2.3** were sustained for 14 hours to 17 hours on a daily basis in mid- to late-July 2013 **(Figure 7-4).**



Note: Logger SC-TT1 may have been exposed to ambient air from July 13, 2013 through September 12, 2013. The data presented in this figure are limited to a subset of the monitored temperatures from June 27, 2013 through July 12, 2013.

Figure 7-3. 2013 temperature logger monitoring data for Mill Creek it's tributary.

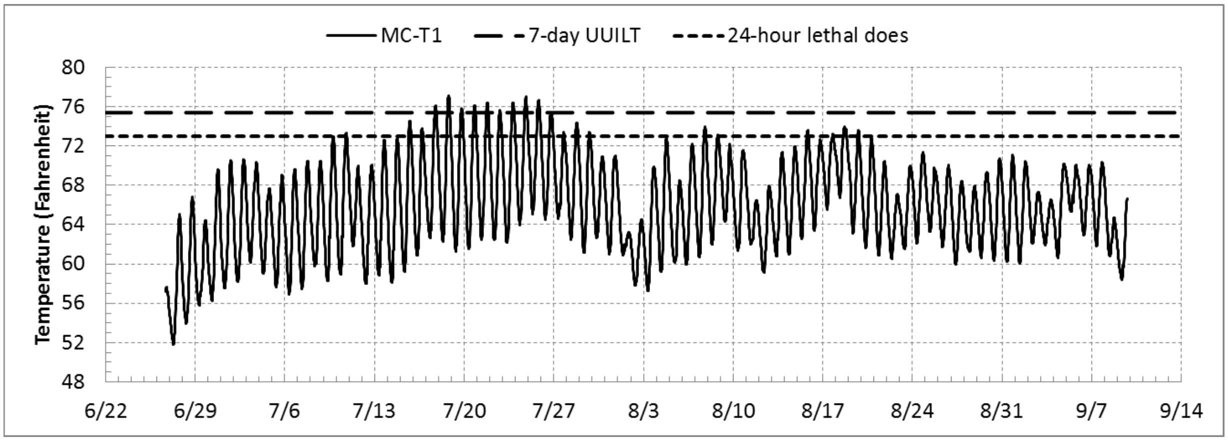


Figure 7-4. Observed diurnal temperatures in Mill Creek upstream of the mouth at logger MC-T1.

The QUAL2K model results (see **Attachment A**) indicate that the maximum naturally occurring summer temperatures in Mill Creek are greater than 66.0°F over most of its length of the impaired segment (green segment in **Figure 7-5**); in this segment, human sources cannot cause the temperature to be exceeded by more than 0.5°F. In a portion of Mill Creek, from river mile 5.57 to 8.46 (red segment in **Figure 7-5**), human sources cannot cause the temperature to be exceeded by more than 1.0°F. Based on the model and temperature data, human sources have caused the allowable change target to be exceeded in the segments from river miles 0 to 1.3 and river miles 2.0 to 6.5; the anthropogenic temperature increase ranged from 0.7°F to 10.3°F, with an average of 3.4°F. From river miles 6.5 to 7.8, which has existing temperatures less than 66.0°F, the anthropogenic increase is less than 0.5°F.

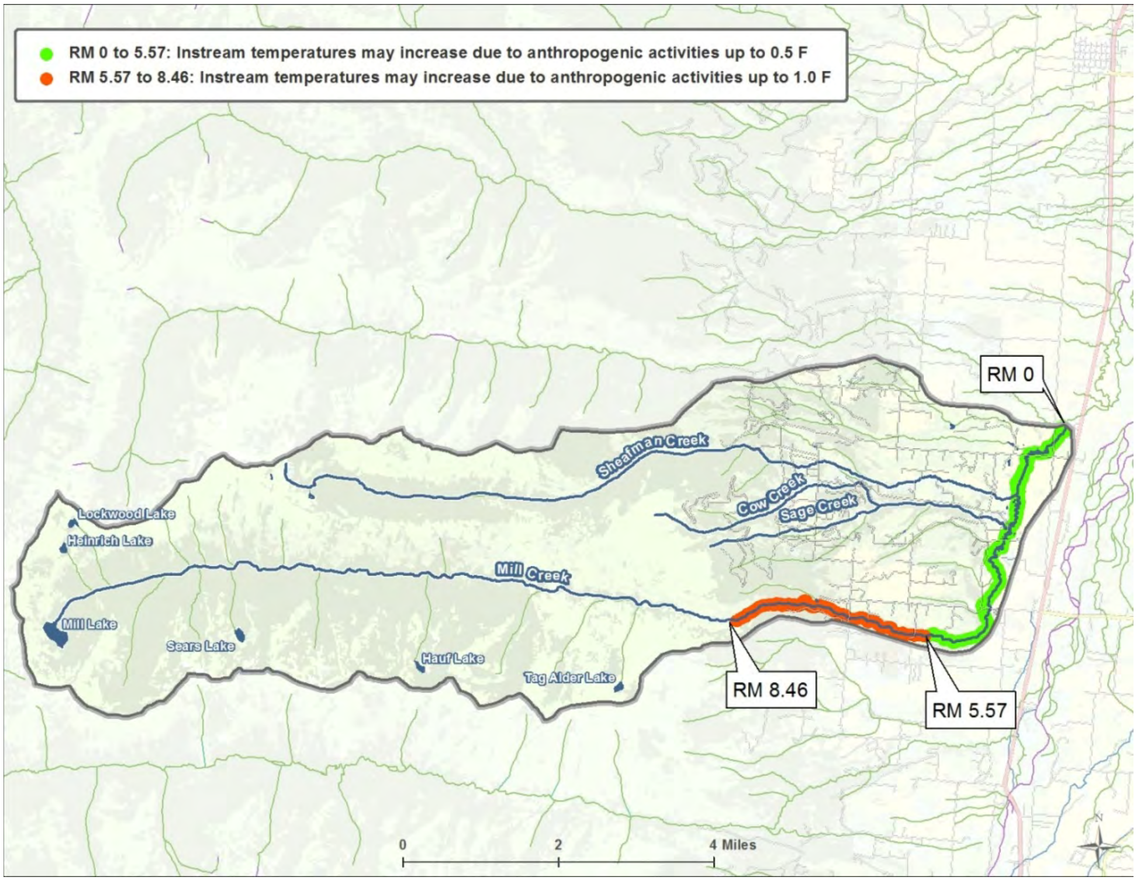


Figure 7-5. Segments of Mill Creek that are subject to different temperature standards.

7.4.4.2 Existing Riparian Shade

Herbaceous vegetation (grass) and shrubs are the most common cover types along Mill Creek, followed by low and medium density trees (**Table 7-2**). Sparse trees, roads, buildings, and bare ground compose only a small percentage of the riparian area. **Figure 7-6** shows the percent difference between the existing effective shade and the target effective shade (based on the Shade Model results provided in **Attachment A**). The greatest shade deficit is in the lower few miles between MC-T3 and MC-T1 where Mill Creek flows through predominantly agricultural lands and the riparian vegetation are dominated by shrubs and grasses that provide minimal shading (i.e., poor shade).

Table 7-2. Composition of the existing riparian buffer 50 feet on both sides of Mill Creek

Land cover type	Area (acres)	Relative area (percent)
Buildings	0.9	0.2%
Bare ground	18.0	4.0%
Herbaceous	213.4	47.0%
Roads	5.2	1.2%
Shrub	98.3	21.7%
Sparse trees	14.8	3.2%
Low density trees	28.7	6.3%
Medium density trees	28.0	6.2%
High density trees	13.8	3.0%
Water	32.9	7.2%

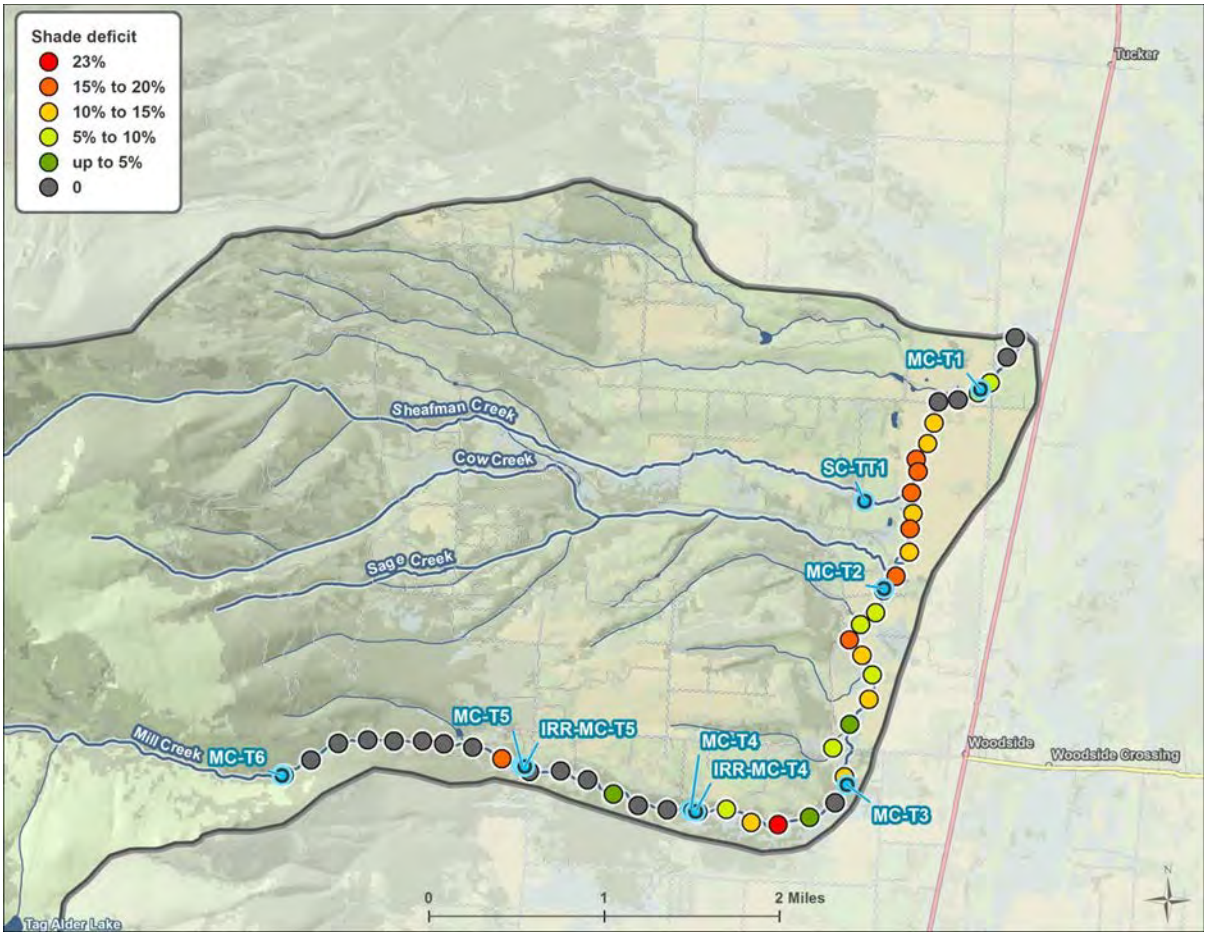


Figure 7-6. The percent of additional effective shade needed to meet the target along Mill Creek.

7.4.5 Summary and TMDL Development Determination

The human-influenced allowable temperature change target is being exceeded along 6.1 miles of the 8.5 mile segment of Mill Creek that was simulated. As described above, stream shading was considered poor. This information supports the existing impairment listing and a temperature TMDL will be developed for Mill Creek.

7.5 Source Assessment

As discussed above, the source assessment largely involved QUAL2K temperature modeling. There are no permitted point sources in the watershed. The watershed has been affected by the road networks, present and historic agricultural activities, and instream flows. Instead of focusing on the potential contribution of these sources, the source assessment focused on two factors that can be influenced by human activities and are drivers of stream temperature: instream flow and riparian shade.

Although channel morphology plays a role in determining effective shade and is an important target, it was not incorporated into the QUAL2K model for either stream. Based on the lack of available data, changing channel morphology was not evaluated as a management scenario.

A QUAL2K model was used to determine the extent that human-caused disturbances within the Mill Creek watershed have increased the water temperatures above the naturally occurring level. The evaluation of model results focuses on the maximum daily water temperatures in Mill Creek during the summer because those are conditions mostly likely to harm aquatic life, the most sensitive beneficial use.

QUAL2K is a one-dimensional river and stream water quality model that assumes the channel is well-mixed vertically and laterally. The QUAL2K model uses steady state hydraulics that simulates non-uniform steady flow. Within the model, water temperatures are estimated based on climate data, riparian shading, and channel conditions. Each stream is segmented into reaches within the model and channel and shade characteristics are uniform throughout each reach. Segmentation is largely based on the location of field data, tributaries, irrigation withdrawal/returns, channel slope, and changes in channel conditions or shading.

Within the model, Mill Creek was segmented into reach lengths of 0.19 miles. The water temperature and flow data collected from Mill Creek and its tributaries in 2013, along with channel measurements, irrigation data, and climate data (**Section 7.3** and **Attachment A**), were used to calibrate and validate the model. The relative error for the daily maximum stream temperatures (at the loggers, modeled versus observed) for the calibration and validation were 0.8% and 1.4%, respectively, indicating the model provides a reasonable approximation of maximum daily temperatures in Mill Creek. While the influence of Mill Creek tributaries was evaluated, the Mill Creek tributaries were not explicitly modeled; only the mainstem of Mill Creek was modeled. Data collected at the mouths of the tributaries were used to simulate the tributaries as unique inputs to the mainstem of Mill Creek, similar to point sources. Human influences on tributary water temperatures (e.g., irrigation withdrawals or shading along the tributaries) were not evaluated.

Flow data at the United States Geological Survey (USGS) gage at West Fork Bitterroot River near Conner, MT (12342500) were evaluated to determine how August streamflow in 2013 (when data were collected) compared to the average August streamflow; flows were at the 65th percentile, indicating they were higher than average.

A baseline scenario and three additional scenarios were modeled to investigate the potential influences of human activities on temperatures in Mill Creek. The following sections describe those modeling scenarios. Although channel width and depth can influence stream temperatures, the existing channel dimensions were not changed for any of the scenarios. A more detailed summary of the development and results of the QUAL2K model are included in **Attachment A**.

7.5.1 Mill Creek Baseline Scenario (Existing Conditions)

The baseline scenario represents stream temperatures under existing measured flows, and meteorological, shade, and channel conditions in August 2013. This is the scenario that all other scenarios are compared against to evaluate the influence of human sources. Based on long-term flow data at the nearby West Fork Bitterroot River USGS gage, flows in August 2013 were at the 65th percentile of flows recorded between 1942 and 2013. Under the baseline scenario, maximum daily temperatures range from about 60°F near the headwaters to 80°F at the mouth (**Figure 7-7**). Temperatures generally increase in a downstream direction.

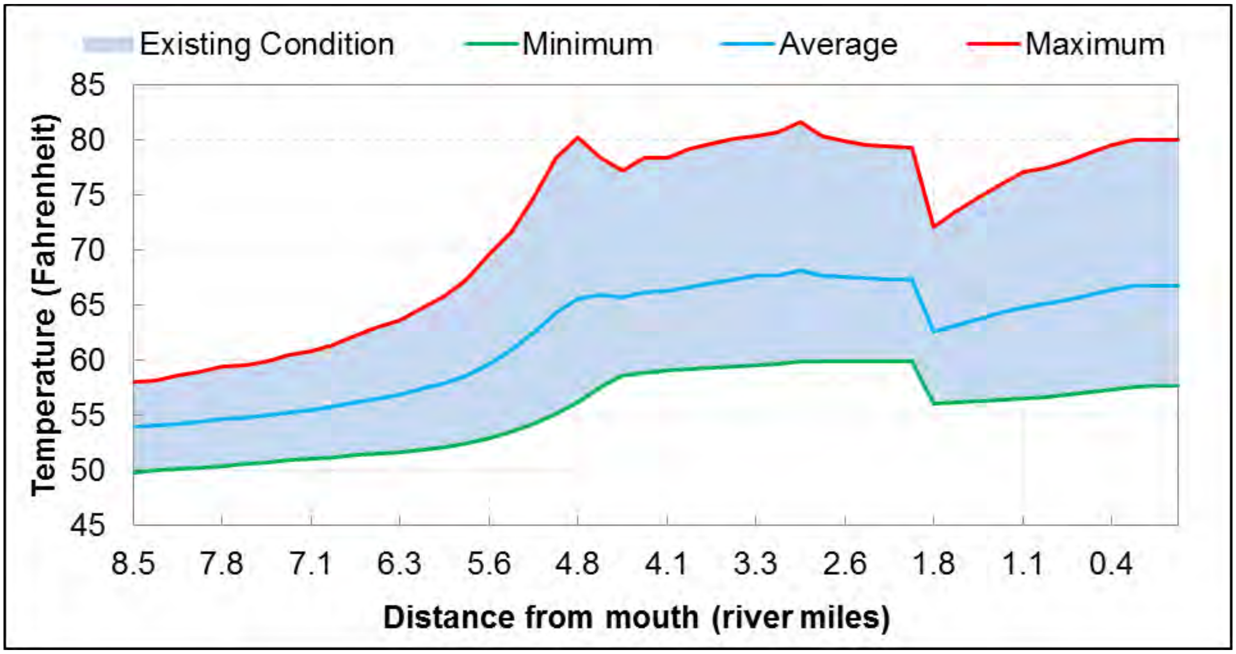


Figure 7-7. Modeled temperatures for the Mill Creek baseline scenario.

7.5.2 Mill Creek Water Use Scenario

A water use scenario was modeled to evaluate the effect that water conservation measures resulting in more instream flow would have on temperatures. In this scenario, the volume of water diverted from Mill Creek for irrigation (which was estimated at about 15 cfs daily, see **Attachment A)** are reduced by 15% within the model and that savings of 2.25 cfs (15.0 * 0.15 = 2.25) is allowed to remain in the stream. It is estimated that a 15% water savings can be achieved through improvements in irrigation water management, irrigation system structural upgrades, and irrigation water delivery system efficiencies. The Irrigation Guide in the National Engineering Handbook from the Natural Resources Conservation Service (NRCS) states typical irrigation system efficiencies for several different types of irrigation systems. This data can be used to determine the effectiveness of irrigation system improvements on water savings. For example, if a field is currently under flood irrigation with an average irrigation efficiency of 35%, by converting to center pivot irrigation, which has an average irrigation efficiency of 85%, the upgraded irrigation system is now 50% more efficient at using the same volume of irrigation water. This allows the irrigator to manage water more efficiently, and reduce runoff or deep percolation (Natural Resources Conservation Service, 1997). These improvements in irrigation efficiency can be used to produce higher crop yields, or ultimately divert less water from the stream. Since leaving additional water instream could lower the maximum daily temperature, converting efficiency savings to a lower amount of water usage is the focus of this scenario.

TMDL development cannot be construed to divest, impair, or diminish any water right recognized pursuant to Title 85 (Montana Code Annotated Section 75-5-705); thus, any voluntary water savings and subsequent instream flow augmentation must be done in a way that protects water rights. In the water use scenario, a 15% reduction in withdrawal volume was used to simulate the outcome of leaving some of the water saved by implementing improvements to the irrigation network in the stream. Considering the statistics presented above from the NRCS Irrigation Guide and other sources that evaluated efficiency improvements for different irrigation practices (Negri et al., 1989; Howell and Stewart, 2003; Osteen et al., 2012) and savings left instream (Kannan et al., 2011), using efficiency gains to reduce withdrawal volume by 15% was selected for the water use scenario. Fifteen percent was chosen to be a reasonable starting point, but as no detailed analysis was conducted of the irrigation network in the Mill Creek watershed, this scenario is not a formal efficiency improvement goal; it is an example intended to represent the application of water conservation practices for water withdrawals.

There are eight points of diversion on Mill Creek distributed from about river mile 8.0 downstream to river mile 5.9 (**Figure 7-1**). The 15% reduction in withdrawal volume would yield an 8.1° F reduction in daily maximum temperature at river mile (RM) 4.8. The temperature difference is significant from river miles 6.3 to 2.0 and 0.4 to the mouth, while the temperature change is less than 0.5° F in the other reaches of Mill Creek (**Figure 7-8**). The water use scenario indicates that irrigation withdrawals are the primary source of temperature impairment along multiple segments.

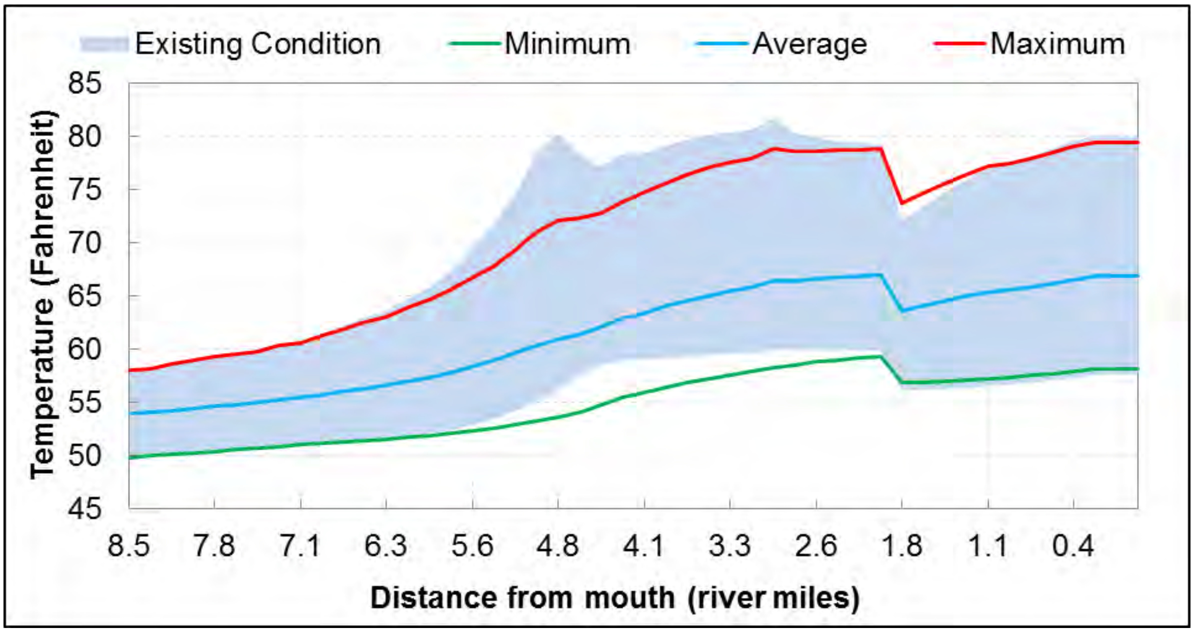


Figure 7-8. Comparison of modeled temperatures in Mill Creek between the water use and baseline scenarios.

7.5.3 Mill Creek Shade Scenario

For the shade scenario, the effective shade inputs to the model were set to represent the target shade condition (**Attachment A**). The shade targets were developed based upon reference condition segments that represent the least impact from anthropogenic activities.

Vegetation communities along Mill Creek from RMs 7.5 to 4.5 (i.e., just upstream of logger MC-T5 to logger MC-T3) are dominated by mixed coniferous/deciduous forest and are impacted by encroachment from residential developments and agriculture. There is opportunity to convert some of the encroached areas to mixed coniferous/deciduous trees. Therefore, shade along this segment will be improved to a reference condition, which is conservatively defined as the segment at logger MC-T3 that is forested and at potential.

Downstream of RM 4.5 (i.e., from logger MC-T3 to the mouth), Mill Creek flows through predominantly low-density residential lands. There is opportunity to improve the vegetation communities in these areas. Therefore, shade along this segment will be improved to a reference condition, which is conservatively defined as the segment at logger MC-T2 that is composed of shrubs in a 50-foot to 100-foot buffer, when the existing average daily effective shade of a given segment is less than 50 percent.

This scenario resulted in maximum daily temperatures ranging from 58.0°F to 80.3°F, which is a decrease from the baseline scenario, which ranged from 58.0°F to 81.7°F (**Figure 7-9**). Meeting the shade target caused an average decrease in the maximum daily temperature of 0.9°F from the baseline scenario. The water temperatures for Mill Creek in this scenario decrease throughout the system, except in the headwaters composed of vegetation already at potential. A maximum change in the maximum daily water temperature of 3.1° F from the existing condition was observed at river mile 4.5. The difference in the daily maximum water temperature between the existing condition and maximum potential shade scenario was greater than 0.5° F from river mile 5.2 to the mouth and was greater than 1.0° F in the following segments: river miles 5.2 to 4.1, 3.5 to 2.8, 2.6 to 1.9, and 1.5 to 0.

The shade scenario indicates that human changes to the riparian vegetation are a source of temperature impairment. To illustrate how this scenario relates to current conditions, the average daily effective shade (which is averaged across all daylight hours) is presented in **Table 7-3** for the baseline scenario and shade scenario.

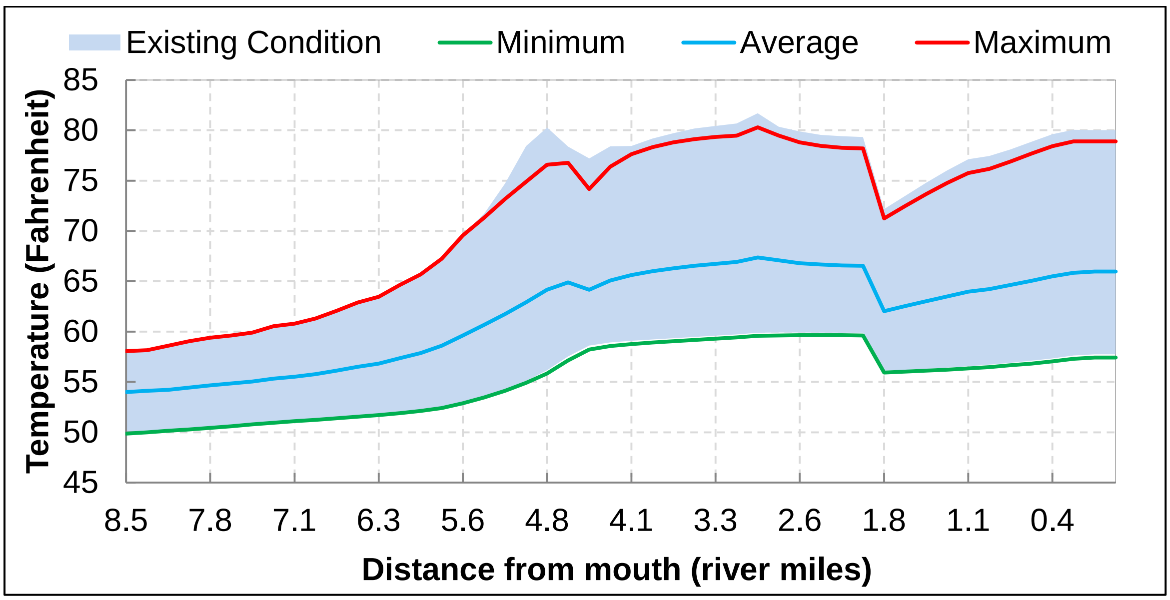


Figure 7-9. Comparison of modeled temperatures in Mill Creek between the shade and baseline scenarios.

Table 7-3. Comparison of effective shade between the existing condition and shade scenario in Mill Creek.

Segment	Existing condition (scenario 1)	Improved shade (scenario 3)
MC-T6 to MC-T5	68%	69%
MC-T5 to MC-T4	61%	61%
MC-T4 to MC-T3	52%	59%
MC-T3 to MC-T2	39%	47%
MC-T2 to Sheafman Creek	36%	46%
Sheafman Creek to MC-T1	39%	48%
MC-T1 to mouth	53%	55%

7.5.4 Mill Creek Naturally Occurring Scenario (Full Application of BMPs with Current Land Use)

The naturally occurring scenario represents Mill Creek water temperatures when all reasonable land, soil, and water conservation practices are implemented (ARM 17.30.602). The naturally occurring scenario is a combination of the shade and water use scenarios. The conditions applied in the water use scenario were included because water conservation is a component of the naturally occurring condition. Water users in the Mill Creek watershed are encouraged to work with the USDA Natural Resource Conservation Service, the Montana Department of Natural Resources and Conservation, the local conservation district, and other local land management agencies to review their irrigation systems, practices, and the variables that may affect overall irrigation efficiency (Negri and Brooks, 1990; Natural Resources Conservation Service, 1997). If warranted and practical, users may consider changes that increase instream flows, and/or reduce warm water return flows in Mill Creek.

The naturally occurring scenario maximum daily temperatures ranged from approximately 58.0 °F to 78.3°F, with an average of 70.0°F. Based on these results, the naturally occurring temperature is greater than 66.0°F for majority of Mill Creek, with the exception of a reach from river mile 8.5 to 5.8. An increase of 0.5°F is allowed from human sources in all areas but river miles 8.5 to 5.8 where human sources are not allowed to increase stream temperatures by more than 1.0°F (**Figure 7-10**).

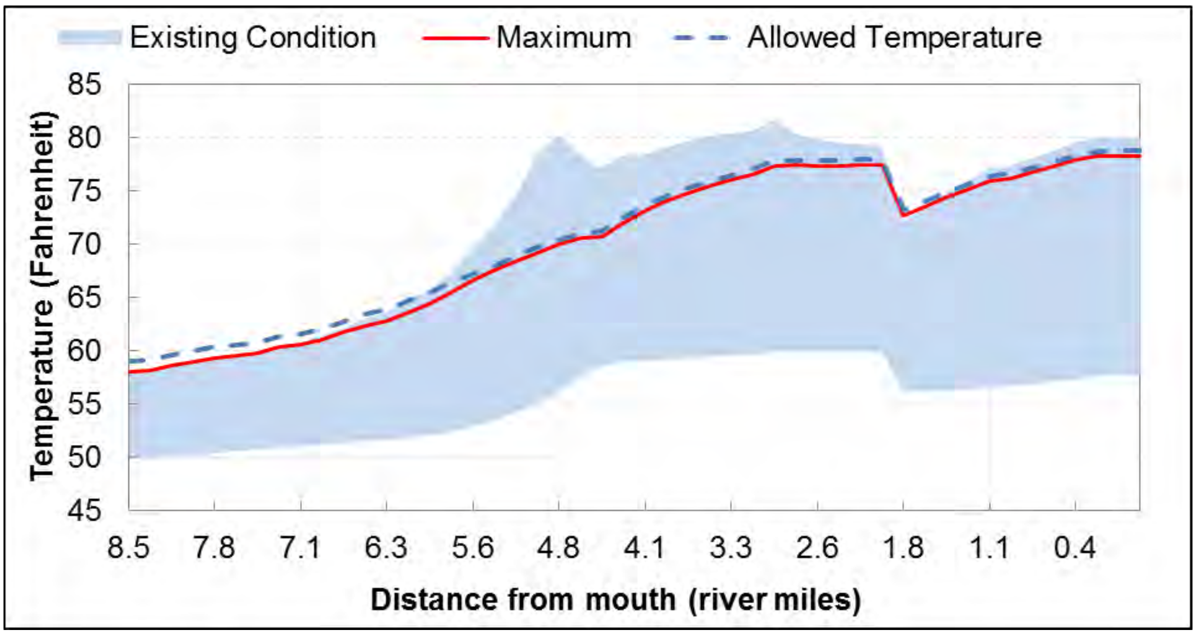
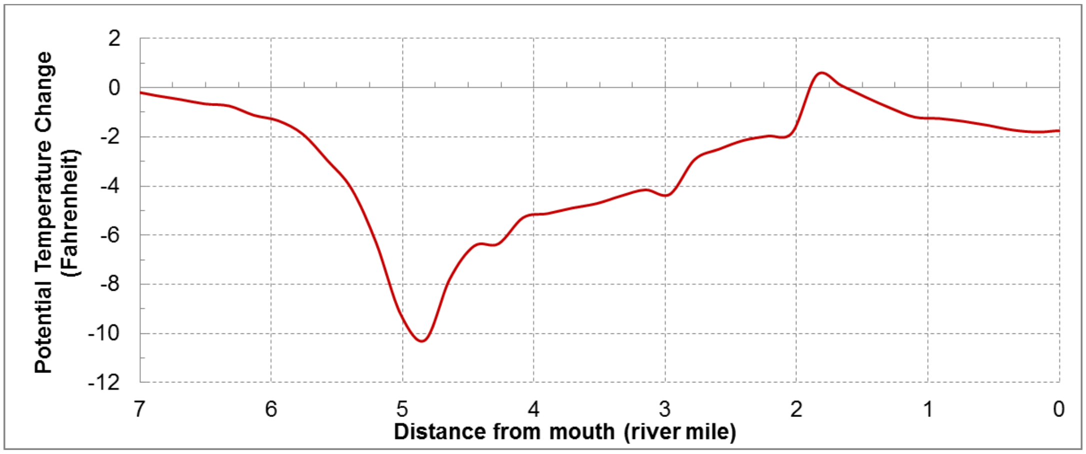


Figure 7-10. The maximum naturally occurring temperature in Mill Creek relative to the existing condition (baseline scenario) and the allowed temperature.

The naturally occurring scenario results indicate there is the potential for significant reductions in stream temperatures relative to the existing condition (baseline scenario): the potential temperature decreases from this scenario as compared to the baseline scenario ranged from 0.7°F to 10.3°F from river mile 6.5 to the mouth (except for one small segment), with an average decrease of 3.4°F (excluding the small segment; **Figure 7-11**). This corresponds to reductions ranging from 0°F to 9.8°F to meet the allowable temperature. Like the water use and shade scenarios, the maximum decrease was in the middle of the watershed, from approximately river miles 6.5 to 2.0. The smallest change was in the reach above river mile 7.8, in the upper portion of the watershed where existing vegetation is currently at or near potential (**Figure 7-12**).



Note: A negative temperature change indicates potential decreases in temperatures from the baseline existing conditions to the naturally occurring conditions.

Figure 7-11. Potential temperature changes in Mill Creek between the baseline (synthetic August weather and low-flow conditions) and naturally occurring scenario.

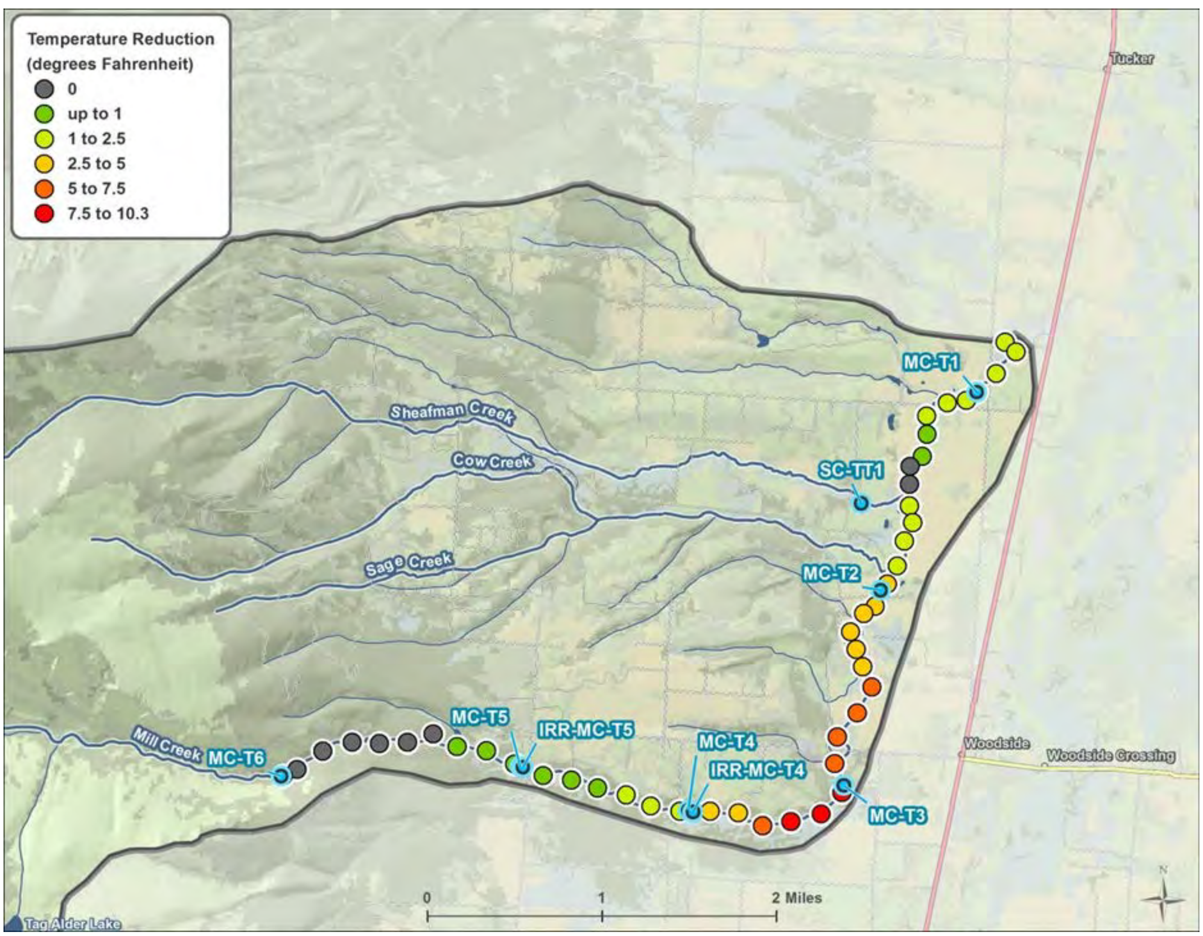


Figure 7-12. Temperature reductions in Mill Creek that can be obtained under naturally occurring conditions (relative to the baseline scenario).

7.5.5 Mill Creek QUAL2K Model Assumptions

The following is a summary of the significant assumptions used during the QUAL2K model development:

- Mill Creek can be divided into distinct segments, each considered homogeneous for shade, flow, and channel geometry characteristics. Monitoring site locations were selected to be representative of segments of Mill Creek.
- Spatial variability of velocity and depth (e.g. stream meander and hyporheic flow paths) are represented through exponents and coefficients of the selected rating curves for each segment.
- Weather conditions at the Smith Creek RAWS are representative of local weather conditions along Mill Creek.
- Shade Model results are representative of riparian shading along segments of Mill Creek.
- Application of some water conservation measures resulting in a 15% decrease in water withdrawn is reasonable and consistent with the definition of the naturally occurring condition.
- The effective shade using two segments of reference conditions is achievable and consistent with the definition of the naturally occurring condition.

7.6 Temperature TMDLs and Allocations

Total maximum daily loads (TMDLs) are a measure of the maximum load of a pollutant that a particular waterbody can receive and still maintain water quality standards (**Section 4.0**). A TMDL is the sum of wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources. A TMDL includes a margin of safety (MOS) to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving stream. Allocations represent the distribution of allowable load applied to those factors that influence loading to the stream. In the case of temperature, thermal loading is assessed.

7.6.1. Temperature TMDL and Allocation Framework

Because stream temperatures change throughout the course of a day, the temperature TMDL is expressed as the instantaneous thermal load associated with the stream temperature when in compliance with Montana's water quality standards. As stated earlier, the temperature standard is defined as follows: The maximum allowable increase over the naturally occurring temperature is 1^{o}F, when the naturally occurring temperature is less than 66^{o}F. Within the naturally occurring temperature range of 66–66.5^{o}F, the allowable increase cannot exceed 67^{o}F. If the naturally occurring temperature is greater than 66.5^{o}F, the maximum allowable increase is 0.5^{o}F. Montana's temperature standard that applies to Mill Creek relative to naturally occurring temperatures is depicted in **Figure 7-13**.

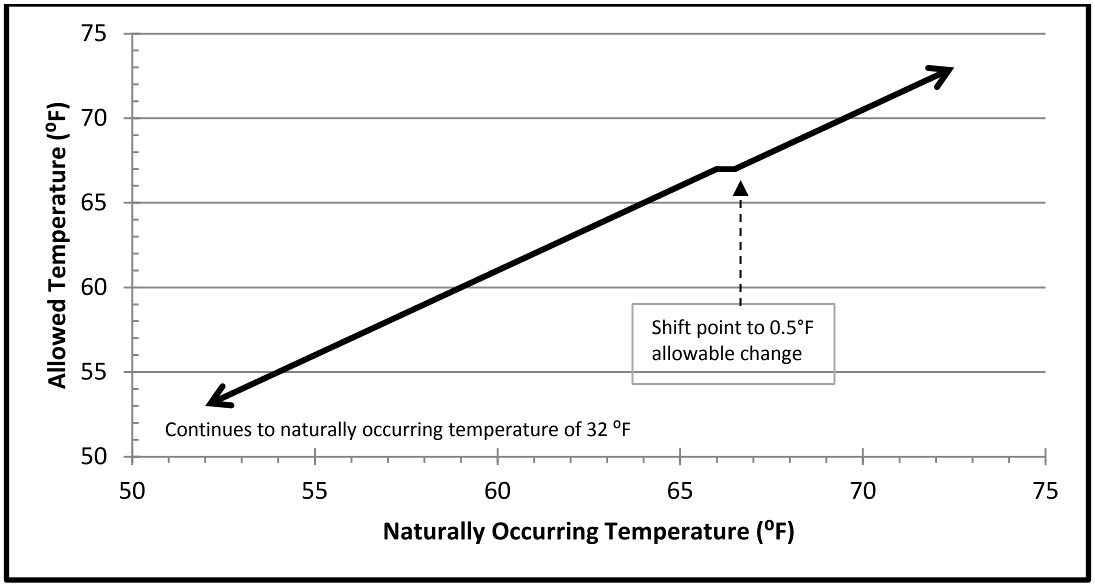


Figure 7-13. Line graph of the temperature standard that applies to Mill Creek

For any naturally occurring temperature over 32°F (i.e., water's freezing point), the allowable instantaneous thermal total maximum load (kilocalories per second [kcal/s]) can be calculated using the standard to identify the allowable human-caused increase (stated above and shown in **Figure 7-13**) and **Equation 7-1.**

Equation 7-1: $TMDL = (((T_{NO} + \Delta) - 32) * 5/9) * Q * 28.3$

Where:

TMDL = allowable thermal load (kcal/s) above 32°F
T_{NO} = naturally occurring water temperature (°F)
Δ = allowable increase above naturally occurring temperature (°F)
Q = streamflow (cfs)
5/9 = conversion factor from degrees Fahrenheit to Celsius
28.3 = conversion factor from degrees Celsius to kcal/s

The instantaneous load is most appropriate expression for a temperature TMDL because water temperatures fluctuate throughout the day and an instantaneous load allows for evaluation of human caused thermal loading during the daytime when fish are most distressed by elevated water temperatures and when human-caused thermal loading would have the most effect. Although EPA encourages TMDLs to be expressed in the most applicable timescale, it also requires TMDLs to be presented as daily loads (Grumbles, Benjamin, personal communication 2006). Any instantaneous TMDL calculated using **Equation 7-1**, which provides a load per second, can be converted to a daily load (kcal/day) by multiplying by 86,400 (i.e., the number of seconds in a day).

Because calculation of the TMDL on any timescale relies on the identification of the naturally occurring condition, which fluctuates over time and within a stream, it generally requires a water quality model. However, the shade, width/depth, and instream flow targets that will be met when all reasonable land, soil, and water conservation practices are applied and the water conservation efforts that fall under the definition of naturally occurring are also measurable components of meeting the TMDL and water quality standard. Meeting targets for effective shade and width/depth, and applying all reasonable water conservation measures collectively provide an alternative method for meeting and evaluating the TMDL that more directly translates to implementation than an instantaneous or daily thermal load.

Therefore, these temperature-influencing measures are being provided as a surrogate TMDL. An example instantaneous TMDL will also be provided. Conceptually, the allocations for the surrogate TMDL and numeric TMDL are the same: the entire load is allocated to natural sources and nonpoint human sources that influence temperature (by altering effective shade, width/depth ratio, and instream flow). Human sources should follow all reasonable land, soil, and water conservation practices.

7.6.2 Temperature TMDL and Allocations

An example TMDL for Mill Creek, expressed as instantaneous load, is presented in **Table 7-4** and the surrogate TMDL and allocations are presented in **Table 7-5**. The example TMDL is a direct translation of the water quality standard into a thermal load. There are no point sources and the entire allowable loads are allocated to natural and human sources that influence temperature.

The example TMDL for Mill Creek is based on the modeled naturally occurring maximum daily temperature at the mouth during August 2013 flows (2.52 cfs). The naturally occurring temperature used in the example is 78.26°F, which means there is an allowable increase of 0.5°F and the allowable temperature would be 78.76°F. The calculation for the example TMDL following **Equation 7-1** is shown below:

$$TMDL = ((78.26 + 0.5) - 32) * 5/9) * 2.52 * 28.3 = 1{,}853 \text{ kcal/second}$$

In this example, the maximum daily stream temperature from the baseline scenario was 80.02°F. With the observed flow, the thermal load was calculated as 1,903 kcal/second.

The surrogate TMDL for Mill Creek contains allocations to temperature-influencing factors that will result in standards attainment when met. Because there are no point sources, there are no wasteload allocations. There is an implicit margin of safety (MOS); the main factor in the MOS is that although there is an allowable increase over the naturally occurring condition, when implementing the TMDL, human sources should follow all reasonable land, soil, and water conservation practices. Additional details about the MOS are described in **Section 7.7**.

Table 7-4. Example Instantaneous Temperature TMDL and Allocation for Mill Creek (at the mouth).

Waterbody	Modeled Existing Load (kcal/sec)	TMDL/Load Allocation (kcal/sec)	Percent Reduction Needed
Mill Creek	1,903	1,853	2.6%

This example represents a condition where a 2 degree reduction is needed to achieve the TMDL. As discussed in **Section 7.5.4**, the needed reductions, based on modeling results along Mill Creek, range from 0 to 9.8 degrees. This means that in many locations, as shown by **Figure 7-11**, the thermal load reduction is significantly greater. Thermal loads can only be calculated at the six locations where flow was monitored. The largest relative temperature differential between the baseline scenario (160 kcal/sec) and the allowed temperature (135 kcal/sec) was at logger MC-T3 (RM 4.6, flow of 0.22 cfs) with a percent reduction of 16%.

Table 7-5. Surrogate Temperature TMDL and Allocations for Mill Creek

Source Type	Surrogate Allocation
Land uses and practices that reduce riparian health and shade provided by near-stream vegetation along Mill Creek	• Improve shade from RMs 7.5 to 4.5 to the reference condition at logger MC-T3 and improve shade from RMs 4.5 to 0 to the reference condition at logger MC-T2.
Inefficient consumptive water use	• Application of all reasonable water conservation practices
Surrogate TMDL	• **Application of all reasonable land, soil, and water conservation practices for human sources that could influence stream temperatures. This primarily includes those affecting riparian shade and instream flow.**

7.6.2.1 Meeting Temperature Allocations

Irrigation water withdrawals and riparian shade are the sources of the impairment. A 15 % improvement in irrigation efficiency was selected to be a reasonable starting point for addressing the impacts associated with water withdrawals. As described previously, water users in the Mill Creek watershed are encouraged to work with the USDA Natural Resource Conservation Service, the Montana Department of Natural Resources and Conservation, the local conservation district, and other local land management agencies to review their irrigation systems, practices, and the variables that may affect overall irrigation efficiency. If warranted and practical, users may consider changes that increase instream flows or reduce warm water return flows in Mill Creek.

DEQ realizes that re-establishment of a riparian overstory and meeting the effective shade target will likely take a long time. In most instances, current management practices are meeting the intent of the allocations, and the commitment to improving water quality needs to be maintained so that the existing riparian vegetation can continue to mature. The targets and allocations represent the desired conditions that would be expected in most areas along the stream, but as discussed relative to shade and water conservation in the target and source assessment sections (Section **7.4.2** and **7.5**), DEQ acknowledges that the allocations may not be achievable at all locations along the stream. The surrogate TMDL provides a measure of conditions that equate to meeting the temperature standard, but the intent and measure of success for all allocations is to follow all reasonable land, soil, and water conservation practices.

7.7 SEASONALITY AND MARGIN OF SAFETY

Seasonality and margin of safety are both required elements of TMDL development. This section describes how seasonality and margin of safety (MOS) were applied during development of the Mill Creek temperature TMDL.

Seasonality addresses the need to ensure year-round beneficial-use support. Seasonality is addressed for temperature in this TMDL document as follows:

- Temperature monitoring and modeling occurred during the summer, which is the warmest time of the year and when instream temperatures are most stressful to aquatic life.
- Effective shade was based on the August solar path, which is typically the hottest month of the year.
- Although the maximum daily temperature was the focus of the source assessment and impairment characterization, because it is mostly likely to stress aquatic life, sources affecting maximum stream temperatures can also alter daily minimum temperatures year-round.

- Addressing the sources causing elevated summer stream temperatures will also address sources that could lower the minimum temperature at other times of the year.
- Temperature targets, the TMDL, and load allocations apply year round, but it is likely that exceedances occur mostly during summer conditions.

The MOS is included to account for uncertainties in pollutant sources and other watershed conditions, and ensure (to the degree practicable) that the TMDL components and requirements are sufficiently protective of water quality and beneficial uses. The MOS is addressed in several ways for temperature as part of this document:

- Although there is an allowable increase from human sources beyond those applying all reasonable land, soil, and water conservation practices, the surrogate allocations are expressed so human sources must apply all reasonable land, soil, and water conservation practices.
- Montana's water quality standards are applicable to any timeframe and any season. The temperature modeling analysis for Mill Creek investigated stream temperatures during summer when effects of increased water temperatures are most likely to have a detrimental effect on aquatic life.
- Compliance with targets and refinement of load allocations are all based on an adaptive management approach (**Section 7.8**) that relies on future monitoring and assessment for updating planning and implementation efforts.

7.8 Uncertainty and Adaptive Management

Uncertainties in the accuracy of field data, source assessments, water quality models, loading calculations and other considerations are inherent when evaluating environmental variables for TMDL development. While uncertainties are an undeniable fact of TMDL development, mitigation and reduction of uncertainty through adaptive management approaches is a key component of ongoing TMDL implementation activities. Uncertainties, assumptions and considerations are applied throughout this document and point to the need for refining analyses when needed.

The process of adaptive management is predicated on the premise that TMDLs, allocations, and their supporting analyses are not static, but are processes that are subject to periodic modification and adjustment as new information and relationships are better understood. As further monitoring and assessment is conducted, uncertainties with present assumptions and consideration may be mitigated via periodic revision or review of the assessment which occurred for this document. As part of the adaptive management approach, changes in land and water management that affect temperature should be tracked. As implementation of restoration projects which reduce thermal input or new sources that increase thermal loading arise, tracking should occur. Known changes in management should be the basis for building future monitoring plans to determine if the thermal conditions meet state standards.

Uncertainty was minimized during data collection because EPA temperature and field data were collected following a Quality Assurance Project Plan (QAPP) (Tetra Tech, 2013) and adhering to DEQ sampling protocols (Montana Department of Environmental Quality, 2005a; Montana Department of Environmental Quality, 2005b). A QAPP was also completed for the QUAL2K model (Tetra Tech, 2013), but there was more uncertainty associated with the model than with the field data because numerous assumptions had to be made to help simulate existing and naturally occurring conditions. Modeling assumptions are briefly described in **Section 7.5.2** but are further detailed within the model reports in **Attachment A**.

The largest source of uncertainty is regarding the targets and conditions used to represent the naturally occurring condition. The target for effective shade from riparian vegetation is intended to represent the reference condition (i.e., highest achievable) and is based on field observations, communication with stakeholders, and best professional judgment. It was selected to be conservative yet achievable. As discussed in the target and source assessment sections (Section **7.4** and **7.5**), the ultimate goal and measure of success is implementation of all reasonable land, soil, and water conservation practices. Irrigation withdrawal measurements for several locations were obtained from the Mill Creek Irrigation District, which helped decrease uncertainty in the baseline scenario. However, current application levels of irrigation best management practices in the Mill Creek watershed were unknown at the time of this study. Because of this, there may be some uncertainty as to the potential for application of new irrigation best management practices (BMPs) in the watershed. Other areas of uncertainty related to the model are associated with assumptions regarding channel dimensions and groundwater temperatures; limited information for those sources was used and applied throughout the watershed. Riparian shade is highly variable in the watershed but a comparison between the field measured effective shade values and values simulated via the Shade Model indicate the model reasonably approximated existing shade conditions within the watershed. Although this uncertainty within the model results in error bars around the modeled temperatures for each scenario, the magnitude of temperature increase caused by human sources still exceeds the allowable change for most of Mill Creek. Additional details regarding uncertainty associated with the model are contained in **Attachment A**.

The TMDLs and allocations established in this section are meant to apply to recent conditions of natural background and natural disturbance. Under some periodic natural conditions, such as fire, it may not be possible to satisfy all targets, loads, and allocations because of natural short-term affects to temperature. Additionally, fire has the potential to alter the long-term vegetative potential. The goal is to ensure that management activities are undertaken to achieve loading approximate to the TMDL within a reasonable time frame and to prevent significant long-term excess loading during recovery from significant natural events.

Any factors that increase water temperatures, including global climate change, could impact thermally sensitive fish species in Montana. The assessments and technical analysis for the temperature TMDL considered a worst case scenario reflective of current weather conditions, which inherently accounts for any global climate change to date. Allocations to future changes in global climate are outside the scope of this project but could be considered during the adaptive management process if necessary.

8.0 NON-POLLUTANT IMPAIRMENTS

Water quality issues are not limited simply to those streams where total maximum daily loads (TMDLs) are developed. In some cases, streams have not yet been reviewed through the water quality assessment process and do not appear on Montana's list of impaired waters, even though they may not be fully supporting all of their beneficial uses. In other cases, a stream may be listed as impaired, but does not require TMDL development because it is determined not to be impaired for a pollutant, but for a non-pollutant (TMDLs are only required for pollutant causes of impairment). Non-pollutant causes of impairment such as "alteration in streamside or littoral vegetative covers" are often associated with sediment, nutrient, or temperature issues, but may be having a deleterious effect on beneficial uses without a clearly defined quantitative measurement or direct linkage to a pollutant. Other examples of non-pollutant causes of impairment can be related to alteration in streamflow regimes and human constructed barriers that prevent fish passage to certain parts of a stream.

Non-pollutant impairments have been recognized by Department of Environmental Quality (DEQ) as limiting their ability to fully support all beneficial uses and are important to consider when improving water quality conditions in both individual streams, and the project area as a whole. **Table 8-1** shows the non-pollutant impairments in the Bitterroot Watershed Project Area on Montana's 2014 list of impaired waters. They are being summarized in this section to increase awareness of the non-pollutant impairment definitions and typical sources. Additionally, the restoration strategies discussed in **Section 9.0** inherently address some of the non-pollutant listings and many of the best management practices (BMPs) necessary to meet TMDLs will also address non-pollutant sources of impairment. As mentioned above, these impairment causes should be considered during planning of watershed scale restoration efforts.

Table 8-1. Waterbody segments with non-pollutant impairments on the 2014 Water Quality Integrated Report

Waterbody & Location Description	Waterbody ID	Impairment Cause
Bass Creek, Selway-Bitterroot Wilderness boundary to mouth (un-named channel of Bitterroot River)	MT76H004_010	Low flow alterations
Bear Creek, Selway-Bitterroot Wilderness boundary to mouth (Fred Burr Creek)	MT76H004_031	Low flow alterations
Bitterroot River, East and West forks to Skalkaho Creek	MT76H001_010	Alteration in streamside or littoral vegetative covers
Bitterroot River, Skalkaho Creek to Eightmile Creek	MT76H001_020	Low flow alterations
Blodgett Creek, Selway-Bitterroot Wilderness boundary to mouth (Bitterroot River)	MT76H004_050	Low flow alterations
Kootenai Creek, Selway-Bitterroot Wilderness boundary to mouth (Bitterroot River)	MT76H004_020	Alteration in streamside or littoral vegetative covers
		Low flow alterations
Lick Creek, headwaters to mouth (Bitterroot River)	MT76H004_170	Chlorophyll-*a*
Lolo Creek, Mormon Creek to mouth (Bitterroot River)	MT76H005_011	Low flow alterations

Table 8-1. Waterbody segments with non-pollutant impairments on the 2014 Water Quality Integrated Report

Waterbody & Location Description	Waterbody ID	Impairment Cause
Lost Horse Creek, headwaters to mouth (Bitterroot River)	MT76H004_070	Low flow alterations
Mill Creek, Selway-Bitterroot Wilderness boundary to the mouth (Fred Burr Creek)	MT76H004_040	Alteration in streamside or littoral vegetative covers
		Low flow alterations
North Channel Bear Creek, headwaters to mouth (Fred Burr Creek)	MT76H004_032	Low flow alterations
North Fork Rye Creek, headwaters to mouth (Rye Creek-Bitterroot River, South of Darby)	MT76H004_160	Alteration in streamside or littoral vegetative covers
Skalkaho Creek, headwaters to mouth (Bitterroot River)	MT76H004_100	Low flow alterations
South Fork Lolo Creek, Selway-Bitterroot Wilderness boundary to mouth (Lolo Creek)	MT76H005_020	Low flow alterations
		Physical substrate habitat alterations
Sweathouse Creek, headwaters to mouth (Bitterroot River)	MT76H004_210	Low flow alterations
Threemile Creek, headwaters to mouth (Bitterroot River)	MT76H004_140	Low flow alterations
Tin Cup Creek, Selway-Bitterroot Wilderness boundary to mouth (Bitteroot River)	MT76H004_080	Alteration in streamside or littoral vegetative covers

8.1 Non-Pollutant Impairment Causes Descriptions

Non-pollutants are often used as a probable cause of impairment when available data at the time of a water quality assessment does not provide a direct, quantifiable linkage to a specific pollutant. In some cases, the pollutant and non-pollutant categories are linked and appear together in the list of impairment causes for a waterbody; however a non-pollutant impairment cause may appear independently of a pollutant cause. The following discussion provides some rationale for the application of the identified non-pollutant causes to a waterbody, and thereby provides additional insight into possible factors in need of additional investigation or remediation.

8.1.1 Alteration in Streamside or Littoral Vegetative Covers

Alteration in streamside or littoral vegetative covers refers to circumstances where practices along the stream channel have altered or removed riparian vegetation and subsequently affected channel geomorphology and/or stream temperature. Such instances may be riparian vegetation removal for a road or utility corridor, or overgrazing by livestock along the stream. As a result of altering the streamside vegetation, destabilized banks from loss of vegetative root mass could lead to overwidened stream channel conditions, elevated sediment and/or nutrient loads, and the resultant lack of canopy cover can lead to increased water temperatures.

8.1.2 Physical Substrate Habitat Alterations

Physical substrate habitat alterations generally describe cases where the stream channel has been physically altered or manipulated, such as through the straightening of the channel or from human-influenced channel downcutting, resulting in a reduction of morphological complexity and loss of habitat (riffles and pools) for fish and aquatic life. For example, this may occur when a stream channel has been straightened to accommodate roads, agricultural fields, or through placer mine operations.

8.1.3 Chlorophyll-*a*

A chlorophyll-*a* impairment occurs when excess levels of chlorophyll-*a* or algae in the stream impairs aquatic life and/or primary contact recreation (Suplee et al., 2009). These high levels of chlorophyll-*a* or algae are caused by excess concentrations of nutrients in the stream which increases algal biomass (Suplee and Sada de Suplee, 2011). Chlorophyll-*a* impairments are typically addressed by nutrient TMDLs, which are found in **Section 5.0** of this document.

8.1.4 Low Flow Alterations

Flow alteration refers to a change in the flow characteristics of a waterbody relative to natural conditions. Streams are typically listed as impaired for low flow alterations when irrigation withdrawal management leads to base flows that are too low to support the beneficial uses designated for that system. This could result in dry channels or extreme low flow conditions unsupportive of fish and aquatic life. It could also result in lower flow conditions which absorb thermal radiation more readily and increase stream temperatures, which in turn creates dissolved oxygen conditions too low to support some species of fish.

It should be noted that while Montana law requires monitoring and assessment to identify threatened or impaired waterbodies (Montana Code Annotated (MCA) 75-5-702) and to subsequently develop TMDLs for these waterbodies (MCA 75-5-703); the law also states that these requirements may not be construed to divest, impair, or diminish any legally recognized water right (MCA 75-5-705). The identification of low flow alterations as a probable source of impairment should not be construed to divest, impair or diminish a water right. Instead it should be considered an opportunity to characterize the impacts of flow alterations and pursue solutions that can result in improved streamflows during critical periods while at the same time ensuring no harm to water rights. These same considerations apply to flow related targets and allocations applied to temperature TMDLs in this document. It is up to local users, agencies, and entities to improve instream flows through water and land management, which may include irrigation efficiency improvements and/or instream water leases that result in reduced amounts of water diverted from streams, particularly during period of reduced streamflow.

8.2 Monitoring and BMPs for Non-Pollutant Affected Streams

Habitat alteration impairments (i.e., alteration in streamside or littoral vegetative covers) for Kootenai Creek, Mill Creek, North Fork Rye Creek, South Fork Lolo Creek, and Tin Cup Creek were addressed in a previous document, the “Bitterroot Temperature and Tributary Sediment Total Maximum Daily Loads and Framework Water Quality Improvement Plan” (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011a).

Chlorophyll-*a* impairment can be linked to nutrient TMDL development in Lick Creek. It is likely that meeting the nutrient TMDL targets will also equate to addressing chlorophyll-*a* impairment in this stream.

Streams listed for non-pollutant impairments should not be overlooked when developing watershed management plans. Attempts should be made to collect sediment, nutrient, and temperature information where data is minimal and the linkage between probable cause, non-pollutant listing, and effects to the beneficial uses is not well defined. The monitoring and restoration strategies that follow in **Sections 9.0** and **10.0** are presented to address both pollutant and non-pollutant issues for streams in the Bitterroot Watershed Project Area with TMDLs in this document, and they are equally applicable to streams listed for the above non-pollutant impairment causes.

9.0 Water Quality Improvement Plan

9.1 Purpose of Improvement Strategy

This section describes an overall strategy and specific on-the-ground measures designed to restore water quality beneficial uses and attain water quality standards in Bitterroot total maximum daily load (TMDL) Planning Area (TPA). The strategy includes general measures for reducing loading from each identified significant pollutant source.

This section should assist stakeholders in developing a watershed restoration plan (WRP) that will provide more detailed information about restoration goals within the watershed. The WRP may also encompass broader goals than the water quality improvement strategy outlined in this document. The intent of the WRP is to serve as a locally organized “road map” for watershed activities, prioritizing types of projects, sequences of projects, and funding sources towards achieving local watershed goals. Within the WRP, local stakeholders identify and prioritize streams, tasks, resources, and schedules for applying best management practices (BMPs). As restoration experiences and results are assessed through watershed monitoring, this strategy could be adapted and revised by stakeholders based on new information and ongoing improvements.

A WRP was completed by the Bitter Root Water Forum in 2014, which addresses water quality impairments in seven subwatersheds on the east side of the Bitterroot valley. This WRP encompasses five waterbodies that are addressed in this document (Rye Creek, North Fork Rye Creek, North Burnt Fork Creek, Ambrose Creek, and Threemile Creek.) Future WRP development can address the water quality issues on the remaining streams in the Bitterroot watershed for which TMDLs have been developed.

9.2 Role of DEQ, Other Agencies, and Stakeholders

The Montana Department of Environmental Quality (DEQ) does not implement TMDL pollutant-reduction projects for nonpoint source activities, but may provide technical and financial assistance for stakeholders interested in improving their water quality by doing such activities. Successful implementation of TMDL pollutant-reduction projects requires collaboration among private landowners, land management agencies, and other stakeholders. DEQ will work with participants to use the TMDLs as a basis for developing locally-driven WRPs, administer funding specifically to help support water quality improvement and pollution prevention projects, and help identify other sources of funding.

Because most nonpoint source reductions rely on voluntary measures, it is important that local landowners, watershed organizations, and resource managers work collaboratively with local and state agencies to achieve water quality restoration goals and to meet TMDL targets and load reductions. Specific stakeholders and agencies that will likely be important to restoration efforts for streams discussed in this document include, but are not limited to:

- Bitterroot Conservation District
- Bitter Root Water Forum
- Bitter Root Land Trust
- Bitterroot River Protection Association
- Clark Fork Coalition
- Five Valleys Land Trust

- Missoula County
- Montana Aquatic Resources Services
- Montana Bureau of Mines and Geology
- Montana Department of Environmental Quality (DEQ)
- Montana Department of Natural Resources and Conservation (DNRC)
- Montana Department of Transportation
- Montana Fish, Wildlife and Parks (FWP)
- Montana Mining Association
- Montana State University Extension Water Quality Program
- Montana Water Center (at Montana State University)
- Natural Resources and Conservation Service (NRCS)
- Ravalli County
- University of Montana Watershed Health Clinic
- U.S. Army Corps of Engineers (USACE)
- U.S. Environmental Protection Agency (EPA)
- U.S. Fish & Wildlife Service (USFWS)
- U.S. Forest Service (USFS)

9.3 Water Quality Restoration Objectives

The water quality restoration objective for the Bitterroot Watershed Project Area is to reduce pollutant loads as identified throughout this document in order to meet the water quality standards and TMDL targets for full recovery of beneficial uses for all impaired streams. Meeting the TMDLs provided in this document will achieve this objective for all identified pollutant-impaired streams. Based on the assessment provided in this document, the TMDLs can be achieved through proper implementation of appropriate BMPs.

A WRP can provide a framework strategy for water quality restoration and monitoring in the Bitterroot Watershed Project Area, focusing on how to meet conditions that will likely achieve the TMDLs presented in this document, as well as other water quality issues of interest to local communities and stakeholders. WRPs identify considerations that should be addressed during TMDL implementation and should assist stakeholders in developing a more detailed adaptive plan in the future. A locally developed WRP will provide more detailed information about restoration goals and spatial considerations but may also encompass broader goals than this framework includes. A WRP would serve as a locally organized “road map” for watershed activities, sequences of projects, prioritizing of projects, and funding sources for achieving local watershed goals, including water quality improvements. The WRP is intended to be a living document that can be revised based on new information related to restoration effectiveness, monitoring results, and stakeholder priorities.

The EPA requires nine minimum elements for a WRP. A complete description can be found at http://www.epa.gov/region9/water/nonpoint/9elements-WtrshdPlan-EpaHndbk.pdf and are summarized here:

1. Identification of the causes and sources of pollutants
2. Estimated load reductions expected based on implemented management measures
3. Description of needed nonpoint source management measures
4. Estimate of the amounts of technical and financial assistance needed
5. An information/education component

6. Schedule for implementing the nonpoint source management measures
7. Description of interim, measurable milestones
8. Set of criteria that can be used to determine whether loading reductions are being achieved over time
9. A monitoring component to evaluate effectiveness of the implementation efforts over time

This document provides, or can serve as an outline, for many of the required elements. Water quality goals for nutrients, metals, and temperature pollutants are detailed in **Sections 5.0, 6.0,** and **7.0**, respectively. These goals include water quality and habitat targets as measures for long-term effectiveness monitoring. These targets specify satisfactory conditions to ensure protection and/or recovery of beneficial uses of the waterbodies in the Bitterroot Watershed Project Area. It is presumed that meeting all water quality and habitat targets will achieve the water quality goals for each impaired waterbody. **Section 10.0** identifies a general monitoring strategy and recommendations to track post-implementation water quality conditions and measure restoration successes.

Habitat Conservation Plans (HCPs) are long-term management plans developed under authorization of the Endangered Species Act and directed toward conservation of key species such as the bull trout and westslope cutthroat trout. In 2010, the US Fish and Wildlife Service (USFWS) approved an HCP for the Montana Department of Natural Resources and Conservation (DNRC), which includes 548,500 acres of state trust land. The DNRC HCP contains similar conservation, implementation, monitoring, and adaptive management approaches to the habitat conservation plan (HCP). These HCPs provide valuable input and can serve as a model for WRPs developed in the Bitterroot Watershed Project Area.

9.4 Overview of Management Recommendations

TMDLs were completed for nine waterbody segments for nutrients, two waterbody segments for metals, and one waterbody segment for temperature,. Other streams in the project area may be in need of restoration or pollutant reduction, but insufficient information about them precludes TMDL development at this time. The following sub-sections describe some generalized recommendations for implementing projects to achieve the TMDLs. Details specific to each stream, and therefore which of the following strategies may be most appropriate, are found within **Sections 5.0, 6.0,** and **7.0**.

In general, restoration activities can be separated into two categories: active and passive. Passive restoration allows natural succession to occur within an ecosystem by removing a source of disturbance. Fencing off riparian areas from cattle grazing is a good example of passive restoration. Active restoration, on the other hand involves accelerating natural processes or changing the trajectory of succession. For example, historic placer mining often resulted in the straightening of stream channels and piling of processed rock on the streambank. These impacts would take so long to recover passively that active restoration methods involving removal of waste rock and rerouting of the stream channel would likely be necessary to improve stream and water quality conditions. In general, passive restoration is preferable for sediment, temperature, and nutrient problems because it is generally more cost effective, less labor intensive, and will not result in short term increase of pollutant loads as active restoration activities may. However, in some cases active restoration is the only feasible mechanism for achieving desired goals; these activities must be assessed on a case by case basis (Nature Education, 2013).

9.4.1 Nutrients Restoration Approach

The goal of the nutrient restoration strategy is to reduce nutrient input to stream channels by increasing the filtering and uptake capacity of riparian vegetation areas, decreasing the amount of bare ground, and limiting the transport of nutrients from rangeland and cropland. Cropland filter strip extension, vegetative restoration, and long-term filter area maintenance are vital BMPs for achieving nutrient TMDLs in predominantly agricultural watersheds. Grazing systems with the explicit goal of increased post-grazing vegetative ground cover are needed to address the same nutrient loading from rangelands. Grazing prescriptions that enhance the filtering capacity of riparian filter areas offer a second tier of controls on the sediment content of upland runoff.

Seasonal livestock confinement areas have historically been placed near or adjacent to flowing streams. Stream channels were the only available livestock water sources prior to the extension of rural electricity. Although limited in size, their repeated use generates high nutrient concentrations in close proximity to surface waters. Episodic runoff with high nutrient concentrations generates large loads that can settle in pools of intermittent streams and remain bio-available through the growing season. Diversion and routing of confinement runoff to harvestable nutrient uptake areas outside of active water courses are effective controls.

In general, these are sustainable grazing and cropping practices that can reduce nutrient inputs while meeting production goals. The appropriate combination of BMPs will differ according to landowner preferences and equipment but are recommended as components of a comprehensive plan for farm and ranch operators. Sound planning combined with effective conservation BMPs should be sought whenever possible and applied to croplands, pastures and livestock handling facilities. Assistance from resource professionals from various local, state, and federal agencies or non-profit groups is widely available in Montana. The local USDA Service Center and county conservation district offices are geared to offer both planning and implementation assistance.

In addition to the agricultural related BMPs, reducing sediment delivery from roads and eroding streambanks is another component of the nutrient reduction restoration plan. Sediment issues in the Bitterroot project area are addressed in a 2011 TMDL document (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011a). It is expected that the sediment related BMPs presented in **Section 8.0** of that plan will also help reduce nutrient loading in impaired tributaries. Sediment TMDLs for Ambrose, Bass, Lick, Muddy Spring, North Burnt Fork, Rye, Sweathouse and Threemile Creeks were included in the 2011 TMDL document.

9.4.2 Metals Restoration Approach

Since the sources of metals related impairments in the Bitterroot Watershed Project Area are unclear, the metals restoration approach cannot be well defined until additional monitoring and source assessment work has been completed to further refine the list of sources leading to impairment. **Section 10.3** describes potential future efforts that can be done to strengthen source assessment and increase available metals related data, while **Appendix D** outlines cleanup and restoration funding options for sources of metals related contamination.

9.4.3 Temperature Restoration Approach

The goal of the temperature restoration approach is to reduce water temperatures where possible to be consistent with naturally occurring conditions. The most significant mechanisms for reducing water temperatures in Mill Creek are increasing riparian shade and maintaining instream flow. Other factors that will help are: improving overwidened portions of the stream, and maintaining conditions where theses creeks are currently meeting the targets.

Increases in shade can be accomplished through the restoration and protection of shade-providing vegetation within the riparian corridor. This type of vegetation can also have the added benefit of improving streambank stabilization to reduce bank erosion, slowing lateral river migration, and providing a buffer to prevent pollutants from upland sources from entering the stream. In some cases, this can be achieved by limiting the frequency and duration of livestock access to the riparian corridor, or through other grazing related BMPs such as installing water gaps or off-site watering. Limiting anthropogenic disturbances in the riparian areas will improve streambank stabilization and riparian vegetation. Other areas may require planting, active bank restoration, and use exclusion to establish vegetation.

The lower segment of Mill Creek (River Mile 2.6 to River Mile 5.6) is considered by Montana Fish Wildlife and Parks to be chronically dewatered; however, it is unknown to what extent instream flow could be increased. If increases in instream summer flows are possible, they can be achieved through a thorough investigation of water use practices and water conveyance infrastructure, and a willingness and ability of local water users to keep more water in the stream. This TMDL document cannot, nor is it intended to, prescribe limitations on individual water rights owners and users. Local water users should work collectively and with local, state, and federal resource management professionals to review water use options and available assistance programs.

Recovery of stream channel morphology in most cases will occur slowly over time following the improvement of riparian condition, stabilization of streambanks, and reduction in overall sediment load. For smaller streams, there may be discrete locations or portions of reaches that demand a more rapid intervention through active physical restoration, but size, scale, and cost of restoration in most cases are limiting factors to applying this type of remedy.

The above approaches give only the broadest description of activities to help reduce water temperatures. The temperature assessment described in **Section 7.4** looked at possible scenarios based on limited information at the watershed scale. Those scenarios showed that improvements in stream temperatures can primarily be made by improvements to riparian shade. It is strongly encouraged that resource managers and land owners continue to work to identify all potential areas of improvement and develop projects and practices to reduce stream temperatures in Mill Creek, as well as other streams in the Bitterroot Watershed Project Area that show the potential for elevated water temperatures.

9.4.4 Non-Pollutant Restoration Approach

Although TMDL development is not required for non-pollutant listings, they are frequently linked to pollutants, and addressing non-pollutant causes, such as flow and habitat alterations, is an important component of TMDL implementation. Non-pollutant listings within the Bitterroot Watershed Project Area are described in **Section 8.0**. Typically, habitat impairments are addressed during implementation of associated pollutant TMDLs. Therefore, if restoration goals within the Bitterroot Watershed Project Area are not also addressing non-pollutant impairments, additional non-pollutant related BMP implementation should be considered.

9.5 RESTORATION APPROACHES BY SOURCE

General management recommendations are outlined below for the major sources of human caused pollutant loads in the Bitterroot Watershed Project Area: agricultural sources, residential development, forestry and timber harvest, riparian and wetland vegetation removal, roads, and mining. Applying BMPs is the core of the nonpoint source pollutant reduction strategy, but BMPs are only part of a watershed restoration strategy. For each major source, BMPs will be most effective as part of a comprehensive management strategy. The WRP developed by local watershed groups should contain more detailed information on restoration goals and specific management recommendations that may be required to address key pollutant sources. BMPs are usually identified as a first effort and further monitoring and evaluation of activities and outcomes, as part of an adaptive management approach will be used to determine if further restoration approaches are necessary to achieve water quality standards. Monitoring is an important part of the restoration process, and monitoring recommendations are outlined in **Section 10.0**. In recognition that noxious weeds are a problem throughout Montana and may be associated with any of the following source categories, noxious weed control should be actively pursued whenever BMPs are being implemented.

9.5.1 Agriculture Sources

Reduction of pollutants from upland agricultural sources can be accomplished by limiting the amount of erodible soil, reducing the rate of runoff, and intercepting eroding soil and runoff before it enters a waterbody. Not all agricultural sources of pollutants discussed in this section were identified in the Bitterroot Watershed Project Area, however, the recommendations below provide a useful guideline for a variety of agricultural activities. The main BMP recommendations for the Bitterroot Watershed Project Area are riparian buffers, wetland restoration, vegetative filter strips, where appropriate, nutrient management, irrigation water management, an prescribed grazing. These methods reduce the rate of runoff, promote infiltration of the soil (instead of delivering runoff directly to the stream), and intercept pollutants. Filter strips and buffers are even more effective for reducing upland agricultural related sediment when used in conjunction with BMPs that reduce the availability of erodible soil such as conservation tillage, crop rotation, and strip-cropping. Additional BMP information, design standards and effectiveness, and details on the suggested BMPs can be obtained from your local USDA Service Center and in Montana's Nonpoint Source Management Plan (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012c).

An additional benefit of reducing sediment input to the stream is a decrease in sediment-bound nutrients. Reductions in sediment loads may help address some nutrient related problems. Nutrient management considers the amount, source, placement, form, and timing of plant nutrients and soil amendments. Conservation plans should include the following information (NRCS Conservation Practice Standard 590 and 590-1, Nutrient Management) (United States Department of Agriculture, Natural Resources Conservation Service, 2005):

- Field maps and soil maps
- Planned crop rotation or sequence
- Results of soil, water, plant, and organic materials sample analysis
- Realistic expected yields
- Sources of all nutrients to be applied
- A detailed nutrient budget
- Nutrient rates, form, timing, and application method to meet crop demands and soil quality concerns

- Location of environmentally sensitive areas, including streams, wetlands, springs, or other locations that deliver surface runoff to groundwater or surface water
- Guidelines for operation and maintenance

9.5.1.1 Grazing

Grazing has the potential to increase sediment and nutrient loads, as well as stream temperatures (by altering channel width and riparian vegetation), but these effects can be mitigated with appropriate management. Development of riparian grazing management plans should be a goal for any landowner who operates livestock and does not currently have such plans. Private land owners may be assisted by state, county, federal, and local conservation groups to establish and implement appropriate grazing management plans. Riparian grazing management does not necessarily eliminate all grazing in riparian corridors. In some areas however, a more limited management strategy may be necessary for a period of time in order to accelerate reestablishment of a riparian community with the most desirable species composition and structure.

Every livestock grazing operation should have a grazing management plan. The NRCS Prescribed Grazing Conservation Practice Standard (Code 528) recommends the plan include the following elements (United States Department of Agriculture, Natural Resources Conservation Service, 2010):

- A map of the operation showing fields, riparian and wetland areas, winter feeding areas, water sources, animal shelters, etc.
- The number and type of livestock
- Realistic estimates of forage needs and forage availability
- The size and productivity of each grazing unit (pasture/field/allotment)
- The duration and time of grazing
- Practices that will prevent overgrazing and allow for appropriate regrowth
- Practices that will protect riparian and wetland areas and associated water quality
- Procedures for monitoring forage use on an ongoing basis
- Development plan for off-site watering areas

Reducing grazing pressure in riparian and wetland areas and improving forage stand health are the two keys to preventing nonpoint source pollution from grazing. Grazing operations should use some or all of the following practices:

- Minimizing or preventing livestock grazing in riparian and wetland areas
- Providing off-stream watering facilities or using low-impact water gaps to prevent ‘loafing’ in wet areas
- Managing riparian pastures separately from upland pastures
- Installing salt licks, feeding stations, and shelter fences in areas that prevent ‘loafing’ in riparian areas and help distribute animals
- Replanting trodden down banks and riparian and wetland areas with native vegetation (this should always be coupled with a reduction in grazing pressure)
- Rotational grazing or intensive pasture management that takes season, frequency, and duration into consideration

The following resources provide guidance to help prevent pollution and maximize productivity from grazing operations:

- Plum Creek Timber Company's Native Fish Habitat Conservation Plan (http://www.plumcreek.com/Environment/nbspSustainableForestrySFI/nbspSFIImplementation/HabitatConservationPlans/tabid/153/Default.aspx)
- USDA, Natural Resources Conservation Service Offices serving Ravalli and Missoula Counties are located in Hamilton and Missoula (find your local USDA Agricultural Service Center listed in your phone directory or on the Internet at www.nrcs.usda.gov)
- Montana State University Extension Service (www.extn.msu.montana.edu)
- DEQ Watershed Protection Section (Nonpoint Source Program): Nonpoint Source Management Plan (http://deq.mt.gov/wqinfo/nonpoint/NonpointSourceProgram.mcpx)

The key strategy of the recommended grazing BMPs is to develop and maintain healthy riparian and wetland vegetation and minimize disturbance of the streambank and channel. The primary recommended grazing BMPs for the Bitterroot project area are providing riparian fencing, limiting livestock access to streams, improving forage use and livestock distribution, provisioning off-stream site watering areas, providing "water gaps" where livestock access to a stream is necessary, planting woody vegetation along streambanks, establishing riparian buffers, and relocating corrals/pens. Although passive restoration via new grazing plans or limited bank re-vegetation are preferred BMPs, in some instances, bank stabilization may be necessary prior to planting vegetation. Other general grazing management recommendations and BMPs to address grazing sources of pollutants and non-pollutant can be obtained in Appendix A of Montana's Nonpoint Source Management Plan (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012c) and in (Harmon, 1999).

9.5.1.2 Flow and Irrigation

Flow alteration and dewatering are commonly considered water quantity rather than water quality issues. However, changes to streamflow can have a profound effect on the ability of a stream to flush sediment and attenuate other pollutants, especially nutrients, metals, and heat. Flow reduction may increase water temperature, allow sediment to accumulate in stream channels, reduce available habitat for fish and other aquatic life, and may cause the channel to respond by changing in size, morphology, meander pattern, rate of migration, bed elevation, bed material composition, floodplain morphology, and streamside vegetation if flood flows are reduced (Andrews and Nankervis, 1995; Schmidt and Potyondy, 2004). Restoration targets and implementation strategies recognize the need for specific flow regimes, and may suggest flow-related improvements as a means to achieve full support of water quality beneficial uses. However, local coordination and planning are especially important for flow management because state law indicates that legally obtained water rights cannot be divested, impaired, or diminished by Montana's water quality law (Montana Code Annotated (MCA) 75-5-705).

Irrigation management is a critical component of attaining both coldwater fishery conservation and TMDL goals. Understanding irrigation water, groundwater, and surface water interactions is an important part of understanding how irrigation practices will affect streamflow during specific seasons.

Some irrigation practices in western Montana are based on flood irrigation methods. Occasionally head gates and ditches leak, which can decrease the amount of water in diversion flows. The following recommended activities could potentially result in notable water savings:

- Install upgraded head gates for more exact control of diversion flow and to minimize leakage when not in operation
- Develop more efficient means to supply water to livestock or crops

- Determine necessary diversion flows and timeframes that would reduce over watering and improve forage quality and production
- Where appropriate, redesign or reconfigure irrigation systems
- Upgrade ditches (including possible lining, if appropriate) to increase ditch conveyance efficiency

Some water from spring and early summer flood irrigation likely returns as cool groundwater to the streams during the heat of the summer. These critical areas could be identified so that they can be preserved as flood irrigation areas. Other irrigated areas which do not contribute to summer groundwater returns to the river should be identified as areas where year round irrigation efficiencies could be more beneficial than seasonal management practices. Winter stream baseflow should also be considered during these investigations.

9.5.1.3 Cropland
The primary strategy of the recommended cropland BMPs is to reduce sediment and nutrient inputs. The major factors involved in decreasing sediment loads are reducing the amount of erodible soil, reducing the rate of runoff, and intercepting eroding soil before it enters waterbodies. The main BMP recommendations for the Bitterroot Watershed Project Area are vegetated filter strips and riparian buffers. Both of these methods reduce the rate of runoff, promote infiltration of the soil (instead of delivering runoff directly to the stream), and intercept sediment. Effectiveness is typically about 70% for the filter strips and 50% for the buffers (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012c). Filter strips and buffers are most effective when used in conjunction with agricultural BMPs that reduce the availability of erodible soil such as conservation tillage, crop rotation, strip cropping, nutrient management, and precision farming. Filter strips along streams should be composed of natural vegetative communities. Additional BMPs and details on the suggested BMPs can be obtained from NRCS and in Appendix A of Montana's Nonpoint Source (NPS) Management Plan (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012c).

9.5.2 Forestry and Timber Harvest
Areas within the Bitterroot Watershed Project Area have been impacted by current and historical timber harvest activities. Timber harvest activities should be conducted by all landowners according to Forestry BMPs for Montana (Montana State University Extension Service, 2001) and the Montana Streamside Management Zone (SMZ) Law (77-5-301 through 307 MCA). The Montana Forestry BMPs cover timber harvesting and site preparation, road building including culvert design, harvest design, other harvesting activities, slash treatment and site preparation, winter logging, and hazardous substances. While the SMZ Law is intended to guide commercial timber harvesting activities in streamside areas (i.e., within 50 ft of a waterbody), the riparian protection principles behind the law should be applied to numerous land management activities (i.e., timber harvest for personal use, agriculture, development). Prior to harvesting on private land, landowners or operators are required to notify the Montana DNRC. DNRC is responsible for assisting landowners with BMPs and monitoring their effectiveness. The Montana Logging Association and DNRC offer regular Forestry BMP training sessions for private landowners.

Buffers of about 50 ft can substantially reduce the amount of sediment and nutrients entering a stream (Lakel et al., 2010; Lee et al., 2003). The SMZ Law protects against excessive erosion within 50 ft of a stream and therefore is an appropriate starting point for helping meet nutrient (especially forms bound to sediments) load allocations (Las). Buffers of greater than 50 ft provide additional protection against sediment and nutrients (Mayer et al., 2005; Wegner, 1999). On USFS Lands, Inland Native Fish Strategy (INFISH) Riparian Habitat Conservation Area guidelines provide significant sediment protection as well as protection from elevated thermal loading (i.e., elevated temperature) by providing adequate shade.

In addition to the BMPs identified above, effects that timber harvest may have on yearly streamflow levels, such as peak flow, should be considered. Timber harvest plans should evaluate the potential for cumulative effects on water yield and peak flow increases and implement BMPs to reduce sediment and nutrients loading.

9.5.3 Riparian Areas, Wetlands, and Floodplains

Healthy and functioning riparian areas, wetlands, and floodplains are critical for wildlife habitat, groundwater recharge, reducing the severity of floods and upland and streambank erosion, and filtering pollutants from runoff. The performance of the above named functions is dependent on the connectivity of riparian areas, wetlands, and floodplains to both the stream channel and upland areas. Human activities affecting the quality of these transitional habitats or their connectivity can alter their performance and greatly affect the transport of water, sediments, and contaminants (e.g., channelization, increased stream power, bank erosion, and habitat loss or degradation). Therefore, restoring, maintaining, and protecting riparian areas, wetlands, and floodplains within the watershed should be a priority of TMDL implementation in the Bitterroot Watershed Project Area.

Initiatives to protect riparian areas and floodplains will help protect property, increase channel stability, and buffer waterbodies from pollutants. However, in areas with a much smaller buffer or where historical vegetation removal and development have shifted the riparian vegetation community and limited its functionality, a tiered approach for restoring stream channels and adjacent riparian vegetation should be considered that prioritizes areas for restoration based on the existing condition and potential for improvement. In non-conifer dominated areas, the restoration goals should focus on restoring natural shrub cover on streambanks. Passive riparian restoration is preferable, but in areas where stream channels are unnaturally unstable or streambanks are eroding excessively, active restoration approaches, such as channel design, woody debris and log vanes, bank sloping, seeding, and shrub planting may be desired to speed up the rate of recovery. Factors influencing appropriate riparian restoration would include the severity of degradation, site-potential for various species, and the availability of local sources as transplant materials. In general, riparian plantings should be designed to promote the establishment of functioning stands of native riparian species. Weed management should also be a dynamic component of managing riparian areas.

Factors influencing the appropriate riparian and wetland restoration would include severity of degradation, site-potential for various species, and availability of local sources for native transplant materials. In general, riparian and wetland plantings would promote establishment of functioning stands of native species. The following recommended restoration measures would allow for stabilization of the soil, decrease sediment delivery to the stream, and increase absorption of nutrients from overland runoff:

- Harvesting and transplanting locally available sod mats with an existing dense root mass provides immediate promotion of bank stability and filtering nutrients and sediments
- Seeding with native graminoids (grasses and sedges) and forbs is a low cost activity at locations where lower bank shear stresses would be unlikely to cause erosion
- Willow sprigging expedites vegetative recovery, but involves harvest of dormant willow stakes from local sources

- Transplanting mature native shrubs, particularly willows (*Salix* sp.), provides rapid restoration of instream habitat and water quality through overhead cover and stream shading, as well as uptake of nutrients

Note: Before transplanting *Salix* from one location to another it is important to determine the exact species so that we do not propagate the spread of non-native species. There are several non-native willow species that are similar to our native species and commonly present in Montana watersheds.

In addition to the benefits described above, it should be noted that in some cases, wetlands act as areas of shallow subsurface groundwater recharge and/or storage areas. The captured water via wetlands is then generally discharged to the stream later in the season and contributes to the maintenance of base flows and stream temperatures. Restoring ditched or drained wetlands can have a substantial effect on the quantity, temperature, and timing of water returning to a stream, as well as the pollutant filtering capacity that improved riparian and wetlands provide.

9.5.4 Residential/Urban Development

There are multiple sources and pathways of pollution to consider in residential and urban areas. Destruction of riparian areas, pollutants from both functioning and failing septic systems, and stormwater generated from impervious areas and construction sites are discussed below.

9.5.4.1 Riparian Degradation

Residential development adjacent to streams can affect the amount and health of riparian vegetation, the amount of large woody debris available in the stream, and might result in placement of riprap on streambanks (see **Section 10.5.5**). As discussed in the above section on riparian areas, wetlands, and floodplains, substantially degraded riparian areas do not effectively filter pollutants from upland runoff.

The number of small acreages is growing rapidly, and many small acreage owners own horses or cattle. Animals grazing on small acreages can lead to overgrazing and a shortage of grass cover, leaving the soil subject to erosion and runoff to surface waters. General BMP recommendations for small acreage lots with animals include creating drylots, developing a rotational grazing system, and maintaining healthy riparian buffers. Small acreage owners should collaborate with Montana State University (MSU) Extension Service, NRCS, conservation districts and agriculture organizations to develop management plans for their lots. Further information may be obtained from the Montana Nonpoint Source Management Plan (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012c) or by contacting the MSU extension (http://www.msuextension.org/).

For landowners, conservation easements can be a viable alternative to subdividing land and can be facilitated through several organizations such as The Nature Conservancy, the Trust for Public Land, and FWP. Further information on conservation easements and other landowner programs can be obtained from FWP (http://fwp.mt.gov/fishAndWildlife/habitat/wildlife/programs/landownersGuide.html).

DEQ encourages the consideration of adopting local zoning or regulations that protect the functions of floodplains and riparian and wetland areas where future growth may occur. Requirements for protecting native vegetation riparian buffers can be an effective mechanism for maintaining or improving stream health. Local outreach activities to inform new residential property owners of the effects of riparian degradation may also prevent such activities from occurring, including providing information on: appropriate fertilizer application rates to lawns and gardens, regular septic system maintenance, preserving existing riparian vegetation, native vegetation for landscaping, maintaining a buffer to protect riparian and wetland areas, and practices to reduce the amount of stormwater originating from developed property. Montana's Nonpoint Source Management Plan contains suggested BMPs to address the effects of residential and urban development, and also contains an appendix of setback regulations that have been adopted by various cities and counties in Montana (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012c). Planning guides and informational publications related to wetlands and native plant species in Montana can be found on DEQ's Wetlands Conservation website at: http://deq.mt.gov/wqinfo/Wetlands/default.mcpx.

9.5.4.2 Septic

Several of the subwatersheds within the Bitterroot Watershed Project Area have very high septic system densities of > 100 septic tanks per square mile. The number of septic systems is likely to increase with future residential development within the Bitterroot Watershed Project Area. Nutrient loading values for septic systems vary depending on soil type and distance to the nearest stream, but typical values for nitrogen and phosphorous loads from individual septic systems are 30.5 lbs/yr and 6.44 lbs/yr, respectively (Montana Department of Environmental Quality, 2009b). However, septic systems should already have minimum design/installation requirements, which should serve as a basic BMP. Older systems should be upgraded and all new systems should meet these minimum requirements.

Some BMPs for septic systems include regular inspection and cleaning and repair of leaking or otherwise malfunctioning systems. As large acreages are subdivided into smaller lots, the number of septic systems in the watershed increases. Plans for development of lands within the Bitterroot project area should consider the effects of additional septic systems to watersheds and consider ways of minimizing septic impacts to water quality such as installing Type II systems to decrease nitrogen loading, installing systems further away from streams to allow for more nutrients attenuation, and/or constructing a wastewater treatment plant (WWTP) to connect multiple wastewater systems.

9.5.4.3 Stormwater

Where precipitation from rain or snowmelt events does not infiltrate soils in urban areas and at construction sites, it drains off the landscape as stormwater, which can carry pollutants into waterways. As the percentage of impervious surfaces (e.g., streets, parking lots, roofs) increases, so does the volume of stormwater and pollutant loads delivered to waterbodies. Although stormwater is not currently identified as a significant source of pollutant contributions for the streams discussed in this document, stormwater management could be a consideration when identifying water quality improvement objectives within the watershed restoration plan. The primary method to control stormwater discharges is the use of BMPs. Additional information can be found in Montana's Nonpoint Source Management Plan (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012c). A guide to stormwater BMPs can be found on EPA's National Menu of Stormwater Best Management Practices at: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm. The Montana Water Center also has a website dedicated to stormwater control for construction activities: http://stormwater.montana.edu/.

9.5.5 Bank Hardening/Riprap/Revetment/Floodplain Development

The use of riprap or other "hard" approaches is not recommended and is not consistent with water quality protection or implementation of this plan. Although it is necessary in some instances, it generally redirects channel energy and exacerbates erosion in other places. Bank armoring should be limited to areas with a demonstrated threat to infrastructure. Where deemed necessary, apply bioengineered bank treatments to induce vegetative reinforcement of the upper bank, reduce stream scouring energy, and provide shading and cover habitat. Limit threats to infrastructure by reducing floodplain development through local land use planning initiatives.

Bank stabilization using natural channel design techniques can provide both bank stability and aquatic habitat potential. The primary recommended structures include natural or “natural-like” structures, such as large woody debris jams. These natural arrays can be constructed to emulate historical debris assemblages that were introduced to the channel by the adjacent cottonwood-dominated riparian community types. When used together, woody debris jams and straight log vanes can benefit the stream and fishery by improving bank stability, reducing bank erosion rates, adding protection to fillslopes and/or embankments, reducing near-bank shear stress, and enhancing aquatic habitat and lateral channel margin complexity.

9.5.6 Unpaved Roads and Culverts

Unpaved roads contribute sediment, as well as nutrients and other pollutants to streams in the Bitterroot Watershed Project Area. Road BMPs can be found on the Montana DEQ or DNRC websites and within Montana’s NPS Management Plan (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012c). Examples include:

- Providing adequate ditch relief up-grade of stream crossings
- Constructing waterbars, where appropriate, and up-grade of stream crossings
- Using rolling dips on downhill grades with an embankment on one side to direct flow to the ditch
- Insloping roads along steep banks with the use of cross slopes and cross culverts
- Outsloping low traffic roads on gently sloping terrain with the use of a cross slope
- Using ditch turnouts and vegetative filter strips to decrease water velocity and sediment carrying capacity in ditches
- For maintenance, grading materials to the center of the road and avoid removing the toe of the cutslope
- Preventing disturbance to vulnerable slopes
- Using topography to filter sediments; flat, vegetated areas are more effective sediment filters
- Where possible, limiting road access during wet periods when drainage features could be damaged

Undersized and improperly installed and maintained culverts can be a substantial source of sediment to streams, and a barrier to fish and other aquatic organisms. Although there are a lot of factors associated with culvert failure and it is difficult to estimate the true at-risk load. As culverts fail, they should be replaced by culverts that pass a 100 year flood on fish bearing streams and at least 25 year events on non-fish bearing streams. Some road crossings may not pose a feasible situation for upgrades to these sizes because of road bed configuration; in those circumstances, the largest size culvert feasible should be used. If funding is available, culverts should be prioritized and replaced prior to failure.

Another consideration for culvert upgrades should be fish and aquatic organism passage. Each fish barrier should be assessed individually to determine if it functions as an invasive species and/or native species barrier. These two functions should be weighed against each other to determine if each culvert acting as a fish passage barrier should be mitigated. Montana FWP can aid in determining if a fish passage barrier should be mitigated, and if so, can aid in culvert design.

9.5.7 Mining

The Bitterroot Watershed Project Area and Montana, more broadly, have a legacy of mining that continues today. Mining activities may have impacts that extend beyond increased metal concentrations in the water. Channel alteration, riparian degradation, and runoff and erosion associated with mining can lead to sediment, habitat, nutrient, and temperature impacts as well. The need for further characterization of impairment conditions and loading sources is addressed through the monitoring plan in **Section 10.3**.

A number of state and federal regulatory programs have been developed over the years to address water quality problems stemming from historic mines, associated disturbances, and metal refining impacts. Some regulatory programs and approaches that may be applicable to the Bitterroot Watershed Project Area include:

- The State of Montana Mine Waste Cleanup Bureau’s Abandoned Mine Lands (AML) Reclamation Program
- The Montana Comprehensive Environmental Cleanup and Responsibility Act (CECRA), which incorporates additional cleanup options under the Controlled Allocation of Liability Act (CALA) and the Voluntary Cleanup and Redevelopment Act (VCRA).
- The federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

More detailed information is included in **Appendix D**.

9.5.7.1 The Surface Mining Control and Reclamation Act (SMCRA)

DEQ’s Abandoned Mines Bureau (AMB) is responsible for reclamation of abandoned mines in Montana. The AMB reclamation program is funded through the Surface Mining Control and Reclamation Act of 1977 (SMCRA). SMCRA funding is collected as a per ton fee on coal production that is then distributed to states by the federal Office of Surface Mining Reclamation and Enforcement. Funding eligibility is based on land ownership and date of mining disturbance. Eligible abandoned coal mine sites have a priority for reclamation construction funding over eligible non-coal sites. Areas within federal Superfund sites and areas where there is a reclamation obligation under state or federal laws are not eligible for expenditures from the abandoned mine reclamation program.

9.5.7.2 Other Historical Mine Remediation Programs

Appendix D provides a summary of mining remediation programs and approaches that can be or may currently be applied within the Bitterroot Watershed Project Area. The extent that these programs may be necessary will depend on the level of stakeholder involvement and initiative throughout the watersheds with metals impairment causes.

9.6 Potential Funding and Technical Assistance Sources

Prioritization and funding of restoration or water quality improvement projects is integral to maintaining restoration activities and monitoring project successes and failures. Several government agencies and also a few non-governmental organizations fund or can provide assistance with watershed or water quality improvement projects or wetlands restoration projects. Below is a brief summary of potential funding sources and organizations to assist with TMDL implementation. **Appendix D** of this document outlines funding sources to assist with mining related TMDL implementation.

9.6.1 Section 319 Nonpoint Source Grant Program

DEQ issues a call for proposals every year to award Section 319 grant funds administered under the federal Clean Water Act. The primary goal of the 319 program is to restore water quality in waterbodies whose beneficial uses are impaired by nonpoint source pollution and whose water quality does not meet state standards. 319 funds are distributed competitively to support the most effective and highest priority projects. In order to receive funding, projects must directly implement a DEQ-accepted watershed restoration plan and funds may either be used for the education and outreach component of the WRP or for implementing restoration projects. The recommended range for 319 funds per project proposal is $10,000 to $30,000 for education and outreach activities and $50,000 to $300,000 for implementation projects. All funding has a 40% cost share requirement, and projects must be administered through a governmental entity such as a conservation district or county, or a nonprofit organization. For information about past grant awards and how to apply, please visit http://deq.mt.gov/wqinfo/nonpoint/319GrantInfo.mcpx.

9.6.2 Future Fisheries Improvement Program

The Future Fisheries grant program is administered by FWP and offers funding for projects that focus on habitat restoration to benefit wild and native fish. Anyone ranging from a landowner or community-based group to a state or local agency is eligible to apply. Applications are reviewed annually in December and June. Projects that may be applicable to the Bitterroot Watershed Project Area include restoring streambanks, improving fish passage, and restoring/protecting spawning habitats. For additional information about the program and how to apply, please visit http://fwp.mt.gov/fishAndWildlife/habitat/fish/futureFisheries/.

9.6.3 Watershed Planning and Assistance Grants

The DNRC administers Watershed Planning and Assistance Grants to watershed groups that are sponsored by a conservation district. Funding is capped at $10,000 per project and the application cycle is quarterly. The grant focuses on locally developed watershed planning activities; eligible activities include developing a watershed plan, group coordination costs, data collection, and educational activities. For additional information about the program and how to apply, please visit http://dnrc.mt.gov/cardd/LoansGrants/WatershedPlanningAssistance.asp.

Numerous other funding opportunities exist for addressing nonpoint source pollution. Additional information regarding funding opportunities from state agencies is contained in Montana's Nonpoint Source Management Plan (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012c) and information regarding additional funding opportunities can be found at http://www.epa.gov/nps/funding.html.

9.6.4 Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is administered by NRCS and offers financial (i.e., incentive payments and cost-share grants) and technical assistance to farmers and ranchers to help plan and implement conservation practices that improve soil, water, air and other natural resources on their land. The program is based on the concept of balancing agricultural production and forest management with environmental quality, and is also used to help producers meet environmental regulations. EQIP offers contracts with a minimum length of one year after project implementation to a maximum of 10 years. Each county receives an annual EQIP allocation and applications are accepted continually during the year; payments may not exceed $300,000 within a six-year period. For additional information about the program and how to apply, please visit http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/.

9.6.5 Resource Indemnity Trust/Reclamation and Development Grants Program

The Resource Indemnity Trust / Reclamation and Development Grants Program (RIT/RDG) is an annual program administered by DNRC that can provide up to $300,000 to address environmental related issues. This money can be applied to sites included on the DEQ Abandoned Mine Lands (AML) priority list, but of low enough priority where cleanup under AML is uncertain. RIT/RDG program funds can also be used for conducting site assessment/characterization activities such as identifying specific sources of water quality impairment. RIT/RDG projects typically need to be administered through a non-profit or local government such as a conservation district, a watershed planning group, or a county. For additional information about the program and how to apply, please visit http://dnrc.mt.gov/cardd/ResourceDevelopment/rdgp/ReclamationDevelopmentGrantsProgram.asp.

9.6.6 Montana Partners for Fish and Wildlife

Montana Partners for Fish and Wildlife is a program under the U.S. Fish & Wildlife Service that assists private landowners to restore wetlands and riparian habitat by offering technical and financial assistance. For additional information about the program and to find your local contact for the Bitterroot River watershed, please visit: http://www.fws.gov/mountain-prairie/pfw/montana/.

9.6.7 Wetlands Reserve Program

The Wetlands Reserve Program is a voluntary conservation program administered by the NRCS that offers landowners the means to restore, enhance, and protect wetlands on their property through permanent easements, 30 year easements, or Land Treatment Contracts. The NRCS seeks sites on agricultural land where former wetlands have been drained, altered, or manipulated by man. The landowner must be interested in restoring the wetland and subsequently protecting the restored site. For additional information about the program and how to apply, please visit http://www.nrcs.usda.gov/wps/portal/nrcs/main/mt/programs/easements/wetlands/

9.6.8 Montana Wetland Council

The Montana Wetland Council is an active network of diverse interests that works cooperatively to conserve and restore Montana's wetland and riparian ecosystems. Please visit their website to find dates and locations of upcoming meetings, wetland program contacts, and additional information on potential grants and funding opportunities: http://deq.mt.gov/wqinfo/wetlands/wetlandscouncil.mcpx.

9.6.9 Montana Natural Heritage Program

The Montana Natural Heritage Program is a valuable resource for restoration and implementation information including maps. Wetlands and riparian areas are one of the 14 themes in the Montana Spatial Data Infrastructure. The Montana Wetland and Riparian Mapping Center (found at: http://mtnhp.org/nwi/) is creating a statewide digital wetland and riparian layer as a resource for management, planning, and restoration efforts.

9.6.10 Montana Aquatic Resources Services, Inc.

Montana Aquatic Resources Services, Inc. (MARS) is a nonprofit organization focused on restoring and protecting Montana's rivers, streams and wetlands. MARS identifies and implements stream, lake, and wetland restoration projects, collaborating with private landowners, local watershed groups and conservation districts, state and federal agencies, and tribes. For additional information about the program, please visit http://montanaaquaticresources.org/.

10.0 Monitoring Strategy and Adaptive Management

10.1 Monitoring Purpose

The monitoring strategies discussed in this section are an important component of watershed restoration, and a requirement of total maximum daily load (TMDL) implementation under the Montana Water Quality Act (Montana Code Annotated (MCA) 75-5-703(7)), and the foundation of the adaptive management approach. Water quality targets and allocations presented in this document are based on available data at the time of analysis. The scale of the watershed analysis, coupled with constraints on time and resources, often result in necessary compromises that include estimations, extrapolation, and a level of uncertainty in TMDLs. The margin of safety (MOS) (**Section 4.4**) is put in place to reflect some of this uncertainty, but other issues only become apparent when restoration strategies are underway. Having a monitoring strategy in place allows for feedback on the effectiveness of restoration activities, the amount of reduction of instream pollutants (whether TMDL targets are being met), if all significant sources have been identified, and whether attainment of TMDL targets is feasible. Data from long-term monitoring programs also provide technical justifications to modify restoration strategies, targets, or allocations where appropriate.

The monitoring strategy presented in this section provides a starting point for the development of more detailed planning efforts regarding monitoring needs; it does not assign monitoring responsibility. Monitoring recommendations provided are intended to assist local land managers, stakeholder groups, and federal and state agencies in developing appropriate monitoring plans to meet the water quality improvement goals outlined in this document. Funding for future monitoring is uncertain and can vary with economic and political changes. Prioritizing monitoring activities depends on funding opportunities and stakeholder priorities for restoration. Once restoration measures have been implemented for a waterbody with an approved TMDL and given time to take effect, Department of Environmental Quality (DEQ) will conduct a formal evaluation of the waterbody's impairment status and determine whether TMDL targets and water quality standards are being met.

10.2 Adaptive Management and Uncertainty

In accordance with the Montana Water Quality Act (Montana Code Annotated (MCA) 75-5-703 (7) and (9)), DEQ is required to assess the waters for which TMDLs have been completed and restoration measures, or best management practices (BMPs), have been applied to determine whether compliance with water quality standards has been attained. This aligns with an adaptive management approach that is incorporated into DEQ's assessment and water quality impairment determination process.

Adaptive management as discussed throughout this document is a systematic approach for improving resource management by learning from management outcomes, and allows for flexible decision making. There is an inherent amount of uncertainty involved in the TMDL process, including: establishing water quality targets, calculating existing pollutant loads and necessary load allocations, and determining effects of BMP implementation. Use of an adaptive management approach based on continued monitoring of project implementation helps manage resource commitments and achieve success in meeting the water quality standards and supporting all water quality beneficial uses. This approach further allows for adjustments to restoration goals, TMDLs, and/or allocations, as necessary.

For an in-depth look at the adaptive management approach, view the U.S. Department of the Interior's (DOI) technical guide and description of the process at: http://www.doi.gov/archive/initiatives/AdaptiveManagement/. DOI includes **Figure 10-1** below in their technical guide as a visual explanation of the iterative process of adaptive management (Williams and Shapiro, 2009).

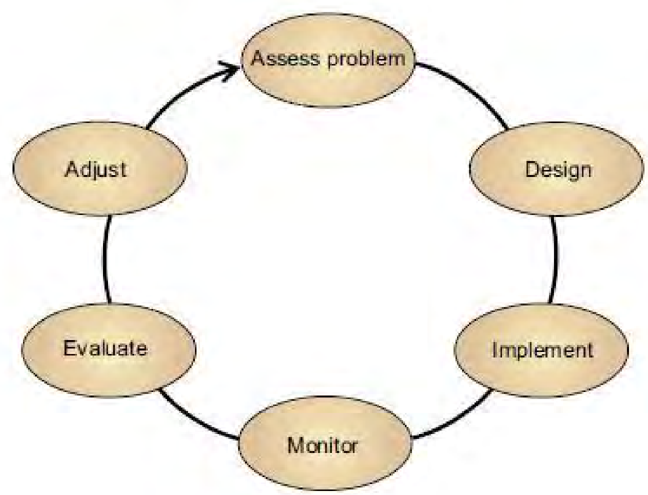


Figure 10-1. Diagram of the adaptive management process

10.3 Future Monitoring Guidance

The objectives for future monitoring in the Bitterroot Watershed Project Area include:

- Strengthen the spatial understanding of sources for future restoration work, which will also improve source assessment analysis for future TMDL review
- Gather additional data to supplement target analysis, better characterize existing conditions, and improve or refine assumptions made in TMDL development
- Gather consistent information among agencies and watershed groups that is comparable to the established water quality targets and allow for common threads in discussion and analysis
- Expand the understanding of streams and nonpoint source pollutant loading throughout the Bitterroot Watershed Project Area beyond those where TMDLs have been developed and address issues
- Track restoration projects as they are implemented and assess their effectiveness

10.3.1 Strengthening Source Assessment

In the Bitterroot Watershed Project Area, the identification of pollutant sources was conducted largely through tours of the watershed, assessments of aerial photographs, the incorporation of geographic information system information, reviewing and analyzing available data, and the review of published scientific studies. In many cases, assumptions were made based on known watershed conditions and extrapolated throughout the project area. As a result, the level of detail often does not provide specific areas on which to focus restoration efforts, only broad source categories to reduce pollutant loads from each of the discussed streams and subwatersheds. Strategies for strengthening source assessments for each of the pollutant categories are outlined below.

Nutrients

- A better understanding of nutrient concentrations in groundwater (as well as the sources) and the spatial variability of groundwater with high nutrient concentrations
- A better understanding of cattle grazing practices and the number of animals grazed in the Bitterroot Watershed Project Area
- A more detailed understanding of nutrient contributions from historical and current mining within the watershed
- A better understanding of septic system contributions to nutrient loads in the nutrient impaired streams
- A review of land management practices specific to subwatersheds of concern to determine where the greatest potential for improvement can occur for the major land use categories
- Additional sampling in streams that have limited data

Metals

- Review data collected by the Lolo Wastewater Treatment Plant (WWTP) as required by the new National Pollutant Discharge Elimination System (NPDES) permit to confirm Environmental Protection Agency's (EPA) 2013 samples are representative of the plant's typical effluent and verify the facility is an insignificant source of lead
- Conduct additional investigations into abandoned mines in the lower Bitterroot River basin to confirm the assumption in this document that lead loading from these sites in fact minimal
- Research further through investigative site visits and groundwater, surface water and soil sampling, the Billingsley Placer Mine, the three historic waste disposal sites near Missoula, and underground gasoline storage tanks to better determine any potential influence they have on the Bitterroot River
- Streambed sediment sampling should also bracket known automobile rip rap sections to verify cars are not contributing to the metals impairment and support the conclusions drawn from the existing US Fish and Wildlife Service (USFWS) soil samples
- Collect soil and bedrock samples in the Lick Creek basin to analyze for aluminum content. Special attention should be paid to the known mineral lick outcrop upstream of EPA sample site C05LICKT01 and any similar mineralized locations. This work will help refine the aluminum contribution from background sources

Temperature

- Field surveys to better identify and characterize riparian area conditions and potential for improvement
- Identification of possible areas for improvement in shading along major tributaries, particularly where riparian vegetation is dominated by grasses due to present and historical land use
- Collection of flow measurements at all temperature monitoring locations during the time of data collection
- Investigation of groundwater influence on instream temperatures, and relationships between groundwater availability and water use in the Mill Creek watershed and the entire Bitterroot Watershed Project Area
- Assessment of irrigation practices and other water use in Mill Creek watershed and Bitterroot Watershed Project Area and potential for improvements in water use that would result in increased instream flows
- Use of additional collected data to evaluate and refine the temperature targets

10.3.2 Increasing Available Data

While the Bitterroot Watershed Project Area has undergone remediation and restoration activities, data are still often limited depending on the stream and pollutant of interest. Infrequent sampling events at a small number of sampling sites may provide some indication of overall water quality and habitat condition. However, regularly scheduled sampling at consistent locations, under a variety of seasonal conditions is the best way to assess overall stream health and monitor change.

Temperature

Temperature investigation for Mill Creek watersheds included seven data loggers, deployed throughout the stream and selected tributaries in summer of 2013. Increasing the number of data logger locations and the number of years of data, including collection of associated flow data, would improve our understanding of instream temperature changes and better identify influencing factors on those changes. Collecting additional stream temperature data in sections with the most significant temperature changes and/or largest spatial gaps between loggers will also help refine the characterization of temperature conditions in Mill Creek. In addition, since shade is a major focus of the allocations, a more detailed assessment of existing riparian conditions and identification of areas for passive and active restoration of riparian vegetation on Mill Creek and its major tributaries is recommended.

Nutrients

Although extensive nutrient data were collected to assist with TMDL development, as conditions change in the respective watersheds with changes in management practices and/or land use, continued monitoring of impaired systems is warranted. When watershed scale monitoring is conducted to assist with future impairment determinations, particular attention should be given to collecting additional nutrient data on impaired streams. Future sampling should also include algal sampling for chlorophyll-*a* and AFDM. Additionally, macroinvertebrates are part of a second tier assessment if nutrient and/or algae concentrations do not clearly indicate impairment and therefore should be collected. Data collection that includes water quality, algal, and macroinvertebrate samples ensures that all aspects of nutrients and their effects on aquatic life can be evaluated.

There are several specific data collection efforts that would better delineate some of the nutrient sources addressed in **Section 5.0**, which include:

- Because there was limited flow data, additional nutrient sampling and flow measurements on all of the impaired streams may help identify whether there are low or high flow issues regarding nutrient loading to further help with source assessment.
- Targeted sampling of Threemile Creek tributaries included in the Wheelbarrow Creek drainage. In the McDowell and Rokosch (2005) report, the Wheelbarrow Creek drainage, which includes Wheelbarrow Creek, Grayhorse Creek, and Spring Gulch, was identified as having important nutrient loads originating in this drainage. These streams were not captured by the DEQ monitoring.
- Because two assessment units (AUs) on the Bitterroot River were previously listed as nutrient impaired, local interests should be concerned with maintaining the unimpaired water quality status and continue monitoring the river and tributaries to ensure the current status is not changing. Continued monitoring will help identify new nonpoint sources and identify impacts, especially from expanding population growth and residential development. In addition, the Bitterroot River is a major tributary to the Clark Fork River, which has a Voluntary Nutrient

Reduction Program, so periodic monitoring is encouraged to ensure that nutrient targets are met.
- Targeted sampling in the Upper Rye Creek watershed to determine if total phosphorus (TP) concentrations are decreasing as the watershed recovers from forest fires. The unnamed creek above the crossing of Moonshine Connection Road with Rye Creek saw a large pulse of TP, so a targeted sampling at various flow regimes may provide further information.
- Targeted sampling of Threemile Creek above the Lee Metcalf National Wildlife Refuge to determine nutrient loads coming into the system. In addition, targeted water quality sampling on the Bitterroot River downstream of this wetland area to see if there is potential influence on nutrient concentrations.
- Additional monitoring in the headwaters of the Bitterroot watershed to collect more reference data to enhance the existing data set and refine natural background concentrations of phosphorus in the watershed. TP in the watershed may be underestimated since the value is based on median concentration values from reference sites in each ecoregion under ideal conditions. Elevated TP concentrations (above target for the Middle Rockies Ecoregion) were found in the upper reaches of the Threemile and Lick watersheds where there was limited human influence.
- Additional monitoring to determine the scope and magnitude of loading from inter-basin transfers of irrigation water. This is especially pertinent to those creeks where inter-basin transfers were identified including: Ambrose, Lick and Threemile Creeks.

Metals

The concepts and assumptions presented in this TMDL are based on the best information available at the time this document was produced. As with any environmental investigation, there are data gaps and portions of the analysis that could be improved upon with the collection of additional data and further study. The information listed below, if available in the future, should be incorporated into the adaptive management approach detailed in **Section 10.2** and can be used to refine source assessments, strengthen or update impairment status determinations, and recognize trends in water quality. DEQ recommends the following actions to improve our understanding of metals-related concerns in the Bitterroot River:

- Conduct additional watershed-wide investigations extending into the upper Bitterroot River segments to determine the influence of the 2000 wildfires and better understand whether the declining trend in metals concentrations is a result of sediment-bound metals issues being resolved passively as contaminates are flushed through the system.
- Conduct synoptic sampling at multiple sites along the lower Bitterroot River segment. The current dataset consists of a sufficient number of water quality samples collected largely from one site (USGS 12352500), however, no paired samples are available from which to draw loading patterns within the segment. Additional synoptic samples would clarify the geographic extent of the lead impairment, potentially highlight source areas where BMP implementation would be most effective, and conclude whether or not the river has assimilative capacity above the Lolo WWTP.
- Collect streambed sediment samples throughout the segment and compare against National Oceanographic and Atmospheric Administration probable effects levels (PEL) values. Only two sediment samples are currently available for the lower Bitterroot River segment and they were collected 15 year ago. New sediment information would help DEQ determine if the high flow water quality exceedance are a consequence of elevated lead concentrations in streambed sediments getting resuspended in the water column. Streambed sediment sampling should also

bracket known automobile rip rap sections to verify cars are not contributing to the metals impairment and support the conclusions drawn from the existing USFWS soil samples.
- Review data collected by the Lolo WWTP as required by the new NPDES permit to confirm EPA's 2013 samples are representative of the plant's typical effluent and verify the facility is an insignificant source of lead.
- Collect additional dissolved aluminum water quality samples. The current dataset consists of only three samples. While the existing samples meet targets, DEQ considers eight samples to be the minimum dataset required to make assessment determinations (Drygas, 2012).
- Collect additional copper water quality samples. The current dataset is sufficiently robust (i.e., 63 samples), however, four aquatic life target exceedances have been observed. Following DEQ's assessment methodology outlined in **Section 7.4.3**, copper is not impairing aquatic life beneficial uses because the exceedance rate is <10%. Future investigations should continue to monitor the impairment status of copper.
- Conduct additional water quality sampling during low flow time periods. In order to address seasonality, DEQ prefers roughly 66% of the samples are representative of low flow conditions (Drygas, 2012). The existing lead dataset collected during low flow conditions represents only 42% of the dataset.
- Conduct additional investigations into abandoned mines in the lower Bitterroot River basin to confirm the assumption in this document that lead loading from these sites is in fact minimal.
- Research further through investigative site visits and groundwater, surface water and soil sampling, the Billingsley Placer Mine, the three historic waste disposal sites near Missoula, and underground gasoline storage tanks to better determine any potential influence they have on the Bitterroot River.
- Conduct additional investigations into the potential for lead loading from road material throughout the watershed that may have originated from contaminated tailings at the Curlew Mine.

DEQ recommends the following actions to improve our understanding of metals-related concerns in Lick Creek:
- Collect soil and bedrock samples in the Lick Creek basin to analyze for aluminum content. Special attention should be paid to the known mineral lick outcrop upstream of EPA sample site C05LICKT01 and any similar mineralized locations. This work will help refine the aluminum contribution from background sources.
- Collect additional iron and lead water quality samples. The existing datasets for these pollutants had aquatic life exceedances but they were not listed as impairing water quality because the exceedance rate was <10%. These iron and lead exceedances were collected during high flow conditions when suspended sediment was elevated, therefore the sources of iron and lead may be controlled through the implementation of the Lick Creek sediment TMDL established in 2011 (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011a).
- Research further the validity of adopting 87 µg/L as the aluminum chronic aquatic life target for waters with pH <6.5 as documented in **Section 7.4.2.1**.

10.3.3 Consistent Data Collection and Methodologies

Data has been collected throughout the Bitterroot Watershed Project Area for many years and by many different agencies and entities; however, the type and quality of information is often variable. Wherever possible, it is recommended that the type of data and methodologies used to collect and analyze the information be consistent so as to allow for comparison to TMDL targets and track progress toward meeting TMDL goals.

DEQ is the lead agency for developing and conducting impairment status monitoring; however, other agencies or entities may work closely with DEQ to provide compatible data. Water quality impairment determinations are made by DEQ, but data collected by other sources can be used in the impairment determination process. The information in this section provides general guidance for future impairment status monitoring and effectiveness tracking. Future monitoring efforts should consult DEQ on updated monitoring protocols. Improved communication between agencies and stakeholders will further improve accurate and efficient data collection. The development of a DEQ approved Sampling Analysis Plan (SAP) and a Quality Assurance Protection Plan (QAPP) will ensure that the data collected meets DEQ standards for data quality.

It is important to note that monitoring recommendations are based on TMDL related efforts to protect water quality beneficial uses in a manner consistent with Montana's water quality standards. Other regulatory programs with water quality protection responsibilities may impose additional requirements to ensure full compliance with all appropriate local, state, and federal laws. For example, reclamation of a mining related source of metals under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Montana Comprehensive Environmental Cleanup and Responsibility Act (CECRA) typically requires source-specific sampling requirements, which cannot be defined at this time, to determine the extent of and the risk posed by contamination, and to evaluate the success of specific remedial actions.

Nutrients

For those watershed groups and/or government agencies that monitor water quality, it is recommended that the same analytical procedures and reporting limits are used so that water quality data may be compared to TMDL targets (**Table 10-1**). In addition, stream discharge should be measured at time of sampling.

Table 10-1. DEQ Nutrient Monitoring Parameter Requirements

Parameter*	Preferred method	Alternate method	Required reporting limit (ppb)	Holding time (days)	Bottle	Preservative
Total Persulfate Nitrogen (TPN)	A4500-NC	A4500-N B	40	28	250mL HDPE	≤6°C (7d HT); Freeze (28d HT)
Total Phosphorus as P	EPA-365.1	A4500-P F	3			H2S04, ≤6°C of Freeze
Nitrate-Nitrite as N	EPA-353.2	A4500-N03 F	10			
Chlorophyll-*a* &	A 10200 H	n/a	n/a	21(pH≥ 7)/ASAP	Filter	Freeze
Ash-Free Dry Weight	A 10300 C(5)	n/a	n/a			
Periphyton	PERI-1/PERI-1mod	n/a	n/a	n/a	50 cm^3 centrifuge tube	Formalin (40% formaldehyde solution)
Macroinvertebrates	EMAP	n/a	n/a	n/a	1L Acid-washed HDPE	Ethanol

*Preferred analytical methods and required reporting limits may change in the future (e.g., become more stringent); consult with DEQ prior to any monitoring effort in order to ensure you use the most current methods.

Metals

Metals monitoring should include analysis of a suite of total recoverable metals (e.g., As, Cu, Cd, Pb, Zn), sediment samples, hardness, pH, discharge, and total suspended solids (TSS). **Table 10-2** identifies the current DEQ metals sampling methodologies and reporting limits for the standard metals suite (water and sediment)(Drygas, 2012).

Table 10-2. DEQ Metals Monitoring Parameter Requirements

Parameter*	Preferred Method	Alternate Method	Req. Report Limit ug/L	Holding Time Days	Bottle	Preservative
Water Sample - Physical Parameters and Calculated Results						
Total Hardness as $CaCO_3$	A2340 B (Calc)		1000			
Total Suspended Solids	A2540D		4000	7	1000 ml HDPE/500 mlHDPE	≤6oC
Water Sample - Dissolved Metals (0.45 um filtered)						
Aluminum	EPA 200.7	EPA 200.8	9	180	250 ml HDPE	Filt 0.45 um, HNO_3
Water Sample - Total Recoverable Metals						
Total Recoverable Metals Digestion	EPA 200.2	APHA3030F (b)	N/A	180	500 ml HDPE/ 250 ml HDPE	HNO_3
Arsenic	EPA 200.8		1			
Cadmium	EPA 200.8		0.03			
Calcium	EPA 200.7		1000			
Chromium	EPA 200.8	EPA 200.7	1			
Copper	EPA 200.8	EPA 200.7	1			
Iron	EPA 200.7		20			
Lead	EPA 200.8		0.3			
Magnesium	EPA 200.7		1000			
Potassium	EPA 200.7		1000			
Selenium	EPA 200.8		1			
Silver	EPA 200.8	EPA 200.7/200.9	0.2			
Sodium	EPA 200.7		1000			
Zinc	EPA 200.7	EPA 200.8	8			
Antimony	EPA 200.8		0.5			
Barium	EPA 200.7	EPA 200.8	3			
Beryllium	EPA 200.7	EPA 200.8	0.8			
Boron	EPA 200.7	EPA 200.8	10			
Manganese	EPA 200.7	EPA 200.8	5			
Nickel	EPA 200.7	EPA 200.8	2			
Thallium	EPA 200.8		0.2			
Uranium, Natural	EPA 200.8		0.2			

Table 10-2. DEQ Metals Monitoring Parameter Requirements

Parameter	Preferred Method	Alternate Method	Req. Report Limit mg/kg (dry weight)	Holding Time Days	Bottle	Preservative
Sediment Sample - Total Recoverable Metals						
Total Recoverable Metals Digestion	EPA 200.2		N/A	180	2000 ml HDPE Widemouth	
Arsenic	EPA 200.8	EPA 200.9	1			
Cadmium	EPA 200.8	EPA 200.9	0.2			
Chromium	EPA 200.8	EPA 200.7	9			
Copper	EPA 200.8	EPA 200.7	15			
Iron	EPA 200.7	EPA 200.7	10			
Lead	EPA 200.8	EPA 200.9	5			
Zinc	EPA 200.7	EPA 200.7	20			
Sediment Sample - Total Metals						
Mercury	EPA 7471B		0.05	28	2000 ml HDPE Widemouth	

*Preferred analytical methods and required reporting limits may change in the future (e.g., become more stringent); consult with DEQ prior to any monitoring effort in order to ensure you use the most current methods

Temperature

It is important that temperature data are collected in consistent locations and using consistent methods. Data loggers should be deployed at the same locations through the years to accurately represent the site-specific conditions over time, and recorded temperatures should at a minimum represent the hottest part of the summer when aquatic life is most sensitive to warmer temperatures. Data loggers should be deployed in the same manner at each location and during each sampling event, and follow a consistent process for calibration and installation. Any modeling that is used should refer to previous modeling efforts (such as the QUAL2K analysis used in this document) for consistency in model development to ensure comparability. In addition, flow measurements should also be conducted using consistent locations and methodology.

10.3.4 Effectiveness Monitoring for Restoration Activities

As restoration activities are implemented, monitoring is valuable to determine if restoration activities are improving water quality, instream flow, and aquatic habitat and communities. Monitoring can help attribute water quality improvements to restoration activities and ensure that restoration activities are functioning effectively. Restoration projects will often require additional maintenance after initial implementation to ensure functionality. It is important to remember that degradation of aquatic resources happens over many decades and that restoration is often also a long-term process. An efficiently executed long-term monitoring effort is an essential component to any restoration effort.

Due to the natural high variability in water quality conditions, trends in water quality are difficult to define and even more difficult to relate directly to restoration or other changes in management. Improvements in water quality or aquatic habitat from restoration activities will most likely be evident in fine sediment deposition and channel substrate embeddedness, changes in channel cumulative width/depths, improvements in bank stability and riparian habitat, increases in instream flow, and changes in communities and distribution of fish and other bio-indicators. Specific monitoring methods, priorities, and locations will depend heavily on the type of restoration projects implemented, landscape or other natural setting, the land use influences specific to potential monitoring sites, and budget and time constraints.

As restoration activities begin throughout the project area, pre and post monitoring to understand the change that follows implementation will be necessary to track the effectiveness of specific projects. Monitoring activities should be selected such that they directly investigate those subjects that the project is intended to effect, and when possible, linked to targets and allocations in the TMDL.

10.3.5 Watershed Wide Analyses

Recommendations for monitoring in the Bitterroot Watershed Project Area should not be confined to only those streams addressed within this document. The water quality targets presented in this document are applicable to all streams in the watershed, and the absence of a stream from the state's impaired waters list does not necessarily imply that the stream fully supports all beneficial uses. Furthermore, as conditions change over time and land management changes, consistent data collection methods throughout the watershed will allow resource professionals to identify problems as they occur, and to track improvements over time.

11.0 STAKEHOLDER AND PUBLIC PARTICIPATION

Stakeholder and public involvement is a component of total maximum daily load (TMDL) planning supported by Environmental Protection Agency (EPA) guidelines and required by Montana state law (Montana Code Annotated (MCA) 75-5-703, 75-5-704) which directs Department of Environmental Quality (DEQ) to consult with watershed advisory groups and local conservation districts during the TMDL development process. Technical advisors, stakeholders and interested parties, state and federal agencies, interest groups, and the public were solicited to participate in differing capacities throughout the TMDL development process in the Bitterroot Watershed Project Area.

11.1 PARTICIPANTS AND ROLES

Throughout completion of the Bitterroot Watershed Project Area TMDLs, DEQ worked to keep stakeholders apprised of project status and solicited input from a TMDL advisory group. A description of the participants in the development of the TMDLs in the Bitterroot Watershed Project Area and their roles is contained below.

Montana Department of Environmental Quality
Montana state law (MCA 75-5-703) directs DEQ to develop all necessary TMDLs. DEQ has provided resources toward completion of these TMDLs in terms of staff, funding, internal planning, data collection, technical assessments, document development, and stakeholder communication and coordination. DEQ has worked with other state and federal agencies to gather data and conduct technical assessments. DEQ has also partnered with watershed organizations to collect data and coordinate local outreach activities for this project.

United States Environmental Protection Agency
EPA is the federal agency responsible for administering and coordinating requirements of the Clean Water Act (CWA). Section 303(d) of the CWA directs states to develop TMDLs (see **Section 1.1**), and EPA has developed guidance and programs to assist states in that regard. EPA has provided funding and technical assistance to Montana's overall TMDL program and is responsible for final TMDL approval. Additionally, partial project management was provided by the EPA Regional Office in Helena, MT.

Conservation Districts
The majority of the Bitterroot Watershed Project Area falls within Ravalli County, with the northern portion in Missoula County. DEQ provided both the Bitterroot Conservation District and Missoula Conservation District with consultation opportunity during development of TMDLs. This included opportunities to provide comment during the various stages of TMDL development, and an opportunity for participation in the advisory group discussed below.

TMDL Advisory Group
The Bitterroot TMDL Advisory Group consisted of selected resource professionals who possess a familiarity with water quality issues and processes in the Bitterroot Watershed Project Area, and also representatives of applicable interest groups. All members were solicited to participate in an advisory capacity per Montana state law (75-5-703 and 704). DEQ requested participation from the interest groups defined in MCA 75-5-704 and included municipalities and county representatives; livestock-oriented and farming-oriented agriculture representatives; timber and mining industry representatives; watershed groups; state and federal land management agencies, tribal representatives; and

representatives of fishing-related business, recreation, and tourism interests. The advisory group also included additional stakeholders with an interest in maintaining and improving water quality and riparian resources.

Advisory group involvement was voluntary and the level of involvement was at the discretion of the individual members. Members had the opportunity to provide comment and review of technical TMDL assessments and reports and to attend meetings organized by DEQ for the purpose of soliciting feedback on project planning. Typically, draft documents were released to the advisory group for review under a limited timeframe, and their comments were then compiled and evaluated. Final technical decisions regarding document modifications resided with DEQ.

Communications with the group members was typically conducted through e-mail and draft documents were made available through DEQ's wiki for TMDL projects (http://montanatmdlflathead.pbworks.com). Opportunities for review and comment were provided for participants at varying stages of TMDL development, including opportunity for review of the draft TMDL document prior to the public comment period.

11.2 Response To Public Comments

Upon completion of the draft TMDL document, and prior to submittal to EPA, DEQ issues a press release and enters into a public comment period. During this timeframe, the draft TMDL document is made available for general public comment, and DEQ addresses and responds to all formal public comments.

The public review period began on September 5, 2014, and ended on October 6, 2014. DEQ made the draft document available to the public, solicited public input and comments, and announced a public meeting at which the TMDLs were presented to the public. These outreach efforts were conducted via e-mails to watershed advisory group members and other interested parties, posts on the DEQ website, and an announcement in the Missoulian (Missoula), the Ravalli Republic (Hamilton). DEQ provided an overview of the TMDLs at a public presentation in Hamilton on September 22, 2014.

During the public comment period, DEQ received comments from three commenters. The comments and accompanying responses are provided below. The original comments are held on file at DEQ and are available upon request.

Comment 1
I have some questions on the TMDL on Bass Creek. What time of year were the samples taken? Where were the samples taken, and from which fork of the creek were they taken? What did you use for a baseline? Thank you for your time on this matter.

> **Response 1**
> DEQ and Tri-State Water Quality Council collected nutrient data in the Bass Creek watershed from 2004 to 2012, including Total Phosphorus (TP), Total Nitrogen (TN), Nitrate + Nitrite, Chlorophyll-a, and AFDM. To meet DEQ's data quality requirements for a nutrients water quality assessment, samples were collected during the summer growing season of July 1 to September 30, which refers to the season for algal growth.
>
> A map of the sampling locations is shown in **Figure 11-1** below. Although Bass Creek appears to branch off below the Forest Service Boundary in aerial views, the data was collected on Bass

Creek as defined in the National Hydrology Dataset and portrayed on the US Topo map produced by the United States Geological Survey (USGS).

The Bass Creek data presented in **Table 11-1** (below) was compared to the nutrient water quality targets for the Idaho batholith Ecoregion III shown in **Table 5-2** (on page 5-5). These target values are the pollution limits and concentration of nutrients above those limits can result in algal growth which can be harmful to fish and other aquatic life as well as harm recreational use. DEQ's water quality assessment method to identify nutrient impairments uses two statistical tests. Bass Creek was determined to be impaired for both total nitrogen and total phosphorus because there were multiple exceedances of the target values (**Table 5-2**) and it failed these statistical tests for both nutrients.

Figure 11-1 Bass Creek Sampling Locations

Table 11-1 Bass Creek Assessment Data

Station (Site) Name	Site ID	Date	Latitude	Longitude	Flow (cfs)	Chl-*a* (mg/m^2)	Total N (mg/L)	NO_2 + NO_3 as N (mg/L)	Total P (mg/L)
Bass Creek (Upper site above Charles Waters campground)	BASSUSFS	8/1/2007	46.57383	-114.14912			0.2	0.007	0.003
Bass Creek (Upper site above Charles Waters campground)	BASSUSFS	8/28/2007	46.57383	-114.14912			0.048	0.013	0.002
Bass Creek (1/4 mile up Bass Creek Trail)	C05BASSC10	7/9/2004	46.57366	-114.14642	E 45			< 0.01	< 0.001
Bass Creek (Below bridge at Larry Creek Loop crossing)	C05BASSC01	8/2/2007	46.5745	-114.1344		3.81	0.12	0.005	< 0.001
Bass Creek (Below bridge at Larry Creek Loop crossing)	C05BASSC01	8/14/2012	46.5745	-114.1344	9.82		< 0.05	< 0.01	< 0.003
Bass Creek (Below bridge at Larry Creek Loop crossing)	C05BASSC01	9/14/2012	46.5745	-114.1344	4.77		< 0.05	< 0.01	< 0.003
Bass Creek (About 1 mile upstream from mouth)	C05BASSC04	8/14/2012	46.57647	-114.11008	0.25	35.2	0.23	< 0.01	**0.029**
Bass Creek (About 1 mile upstream from mouth)	C05BASSC04	9/14/2012	46.57647	-114.11008	0.12				0.01
Bass Creek (About 150 yards upstream from Hoblitt Lane)	C05BASSC20	7/9/2004	46.57577	-114.09946	E 0.75			0.01	**0.037**
Bass Creek (About 150 yards upstream from Hoblitt Lane)	C05BASSC20	8/14/2012	46.57577	-114.09946	0.8	31.9	0.24	< 0.01	0.022
Bass Creek (About 150 yards upstream from Hoblitt Lane)	C05BASSC20	9/14/2012	46.57577	-114.09946	0.42		0.17		0.015
Bass Creek (South Fork at Hwy 93 crossing)	C05BASSC02	8/14/2012	46.5741	-114.0945	2.1		**0.81**	< 0.01	**0.152**
Bass Creek (South Fork at Hwy 93 crossing)	C05BASSC02	9/14/2012	46.5741	-114.0945	1.06		0.26	0.04	**0.031**
South Bass Creek (Below Hwy 93 bridge)	BASS93S	8/1/2007	46.5739	-114.09414			**0.6**	0.018	**0.089**
South Bass Creek (Below Hwy 93 bridge)	BASS93S	8/28/2007	46.5739	-114.09414			**0.33**	0.013	**0.058**

E = Estimated

A “<” symbol indicates a non-detect sample. The detection limit is entered after the “<” symbol.

Bolded values exceed the nutrient water quality target

Comment 2

2a. Section 7.0 addresses the temperature components of the document. The document refers to “naturally occurring” temperature regimes in the stream; however, the analysis to arrive at the “naturally occurring” stream conditions are not made explicit.

My primary concern is that long-term climate change may not be reflected adequately in the model. The document notes that the base-line water temperature estimates are based on existing climate data, in addition to, riparian shading and channel conditions. Adequate time scale of climate data is needed to establish an appropriate base-line. I note a caveat is made in the document that the analysis “inherently accounts for any climate change to date” (7-22). However, when I asked DEQ at a public meeting on Sept. 22, 2014 in Hamilton what the oldest climate data used for analysis was, they indicated that the data encompassed the previous 50 years. If that is the case, the calculations to determine “naturally occurring” stream temperatures may be incorporating a shifting baseline from actually naturally occurring temperatures. Pederson *et al.* have noted that seasonal averages have been increasing for at least 100 years. They also note that the increase in seasonal averages and temperature extremes is two to three times greater in western Montana than global averages. A model using only the previous 50 years of data would therefore underestimate the true naturally occurring stream temperature.

I recognize that anthropogenic climate change is outside of the scope of impairments that the DEQ can make intra-watershed recommendations for; however, other such agents of impairment (e.g. road networks, agricultural activities, and in-stream flow) are still noted in the document. The DEQ should indicate within the document how naturally occurring temperature estimates are establish, and especially address how the agency incorporates the latest estimates of climate change into the model.

2b. The study areas addressed within this TMDL for most streams originating in the Selway-Bitterroot is inconsistent. Three creeks addressed in the document originate in the Selway-Bitterroot Wilderness: Bass, Mill, and Sweathouse Creeks. The TMDL lists the upstream limit of the TMDL for Bass Creek and Mill Creek as the US Forest Service Wilderness Boundary. The upstream limit of the study area for Sweathouse Creek, however, is listed as the stream’s headwaters. There is no justification in the document explaining why the DEQ decided to discontinue study of Bass and Mill Creek before their headwaters. I suggest that the DEQ either provide a justification for this inconsistency, or extend the length of stream considered to incorporate the entire stream to the headwaters of Bass and Mill creek.

2c. Section 10.0 “Monitoring Strategy and Adaptive Management,” provides a comprehensive list of suggested monitoring strategies, but provides no timeline in which these studies should be completed nor objective goals for carrying out such monitoring. Considering DEQ’s limitation on usable data within the previous 10 years, it seems a timeline for monitoring would be useful, even if only a tentative and adaptable timeline is presented. I suggest that the DEQ add a “best-case” scenario timeline and objective goals for the monitoring strategy suggested in this TMDL document.

Response 2

2a. As stated in **Section 7.4.1** of the document, Montana’s water quality standard for temperature is narrative, in that it specifies a maximum allowable increase above the naturally occurring temperature to protect fish and aquatic life. Under this consideration, Montana water quality law would define naturally occurring temperatures as any simulated temperature where natural and human sources are minimized by applying all reasonable land, soil, and water conservation practices. Naturally occurring water temperatures therefore can be estimated for a given set of conditions using QUAL2K or other modeling approaches, relying on meteorological forcing functions that are inclusive of air temperature, dew point, wind speed, incoming solar radiation, cloud cover and atmospheric conditions (atmospheric turbidity or transmission), along with shade and morphological conditions that are appropriate for the present time of analysis.

Naturally occurring temperatures for Mill Creek were estimated by modeling a reference shade and flow condition to the existing conditions on the river (see **Section 7.5.4**), with the assumption that the appropriate best management practices would be in place, representing the application of all reasonable land, soil , and water conservation practices. The baseline (existing conditions) therefore represents stream temperatures under existing measured flows, channel conditions (e.g., shade and morphology), and meteorological conditions in August 2013. Long term climate data were used for the sole purposes of comparing to flow and climate data from August 2013 to see how much that year varied from average flows and climate, as noted in **Attachment A-Appendix A**. Both the modeled baseline and naturally occurring conditions were modeled on the hottest day with the lowest streamflow in 2013, in order to provide a conservative estimate of current conditions on the stream during the time period that would have the most impact on aquatic life.

That said, DEQ recognizes that future climate change has the potential to impact stream temperatures; but this does not affect the current impairment determination for Mill Creek, nor would it change the recommended strategies for improving water temperature. DEQ found the stream to be impaired when comparing the naturally occurring scenario to the existing condition, and if flow and or temperature conditions worsened due to climate change, the stream would most likely still be impaired.

However, if DEQ sees the potential for delisting a temperature impaired stream, a scenario can be run to see what impact extreme low flows have on temperatures (DEQ could also apply this to any hypothetical climate change scenario if it had a potential effect on the impairment determination). An example of this can be found on South Fork Antelope Creek in the Rock Creek Watershed TMDL document in **Section 6.5.2** of that document (Montana Department of Environmental Quality, 2013). A scenario was run where flows were decreased to represent stream dynamics during an exceptionally dry season under low-flow conditions. This scenario was also run in conjunction with the reference shade condition. DEQ found that even under an extremely dry year, with reference shade in place, the stream would still not be impaired and therefore could be delisted.

The TMDL process is adaptive. Meaning, in the future if conditions change, those conditions can be evaluated in the model and scenarios can be re-run to see if impairment determinations should change, due to climate change or other unknown factors.

2b. Thank you for identifying this inconsistency in the assessment unit boundaries for the streams on the west side of the Bitterroot valley. When Sweathouse Creek first appeared on the 2002 303(d) List, the assessment unit was incorrectly defined as “headwaters to mouth (Bitterroot River)”. It should have been defined the same as the other streams “Selway-Bitterroot Wilderness boundary to the mouth (Bitterroot River)”, and will be corrected in the upcoming 2016 303(d)/305(b) Integrated Report. This change does not affect the TMDL for Sweathouse Creek.

2c. The "Monitoring Strategy and Adaptive Management" section in this document, or **Section 10.0**, is intended to assist stakeholders in the watershed with the development of a Watershed Restoration Plan (WRP) and provide guidance to future monitoring efforts. The WRP is a document that is developed by stakeholders in the watershed to identify potential restoration efforts in the watershed, as well as provide timelines on when those activities will be completed. Because nonpoint source pollution restoration activities are voluntary, as defined in Montana Code Annotated (MCA) section 75-5-703(6), DEQ cannot accurately define or set timelines on when these activities will be completed, but instead can assist stakeholders in the development of a WRP to more accurately define those timelines. By engaging stakeholders through the development of the WRP, nonpoint source pollution restoration activities are implemented at a local level, and are therefore more likely to succeed because the local stakeholders are invested in the process. DEQ's role is to provide technical and possibly financial assistance to these local stakeholder groups to assist them in their goals of implementing the TMDL. There is a monitoring component in the WRP, and the types of restoration activities planned will determine the monitoring needed. The need for future monitoring on a particular waterbody to see if the goals of the TMDL are being met is dependent on the level of restoration work that is occurring in the watershed.

Comment 3

3a. Our basic concern about the Bitterroot Watershed TMDL is that the plan to bring impaired streams into compliance with the law is lacking in any crucial compliance enforcement. The agency admits that all compliance enforcement on nonpoint source reductions is voluntary. That means there is no guarantee that these actions will be taken. "Ideally", as you put, they would occur and would have the needed effects in terms of reductions, but there is no requirement that these actions be taken or that these BMPs be implemented. The only requirements you have to enforce the measures needed to meet TMDLs is in controlling the permits of point sources. In this case there are no point sources on the eleven tributaries that are contributing polluted water so you have no control. In the two most recent permit applications for point source pollution in the Bitterroot Watershed the agency has failed to do any analysis or require any monitoring concerning of the contribution that may be made to the Bitterroot River. Although the Bitterroot River is not considered impaired at this point to nutrients, it does state in the TMDL that:

"Because two AUs on the Bitterroot River were previously listed as nutrient impaired, local interests should be concerned with maintaining the unimpaired water quality status and continue monitoring the river and tributaries to ensure the current status is not changing. Continued monitoring will help identify new nonpoint sources and identify impacts, especially from expanding population growth and residential development. In addition, the Bitterroot River is a major tributary to the Clark Fork River, which has a Voluntary Nutrient Reduction Program, so periodic monitoring is encouraged to ensure that nutrient targets are met".

It seems that even where your agency could use the permitting system to protect the Bitterroot Watershed you are not doing so. This basic flaw in your recovery plan is fatal, in our opinion, and renders the plan potentially ineffective and obviously, for the most part, unenforceable.

3b. As I mentioned at your meeting in Hamilton, there are a few possible sources of lead in the lower Bitterroot River that were not considered in the TMDL. One would be the shooting range that was operated on the Schroeder Ranch for several years. It was a clay shooting operation that I visited. It may have been discontinued under new ownership since the Schroeders sold the place a few years ago. It was located in a steep gully just above the river.

A very probable source of the lead could be from the Curlew Mine. Those slag piles were used by county and private contractors for over 40 years to gravel roads, primarily in the north valley due to the cost of hauling to the south valley and the proximity of other sources. The gravel at Curlew was preferred because it could be accessed and used without cost for a lot of the time.

Thank you for considering our comments.

Response 3

3a. You are correct in stating that nonpoint source pollution reductions are voluntary, which is defined in Montana Code Annotated (MCA) section 75-5-703(6). Voluntary conservation efforts are extremely important in the implementation of the TMDL, and there are many organizations and programs to assist landowners in the implementation of best management practices (BMPs), as identified in **Section 9.6**. Through voluntary conservation, landowners are more likely to implement and maintain the appropriate BMPs to address the particular resource concern. The three key components of a BMP are that it must be technically feasible, financially feasible, and socially acceptable.

For example: If a landowner has streambank erosion issues related to livestock grazing on his property, he may install riparian fencing and off-site watering facilities for his livestock to remedy the issue. Although there is some upfront cost to this BMP, the landowner is able to get some financial assistance through the Natural Resources Conservation Service (NRCS) - Environmental Quality Incentives Program (EQIP) program, as well as engineering support from the NRCS to design this watering system. After installing the BMP, the landowner notices that by redistributing his livestock out to different parts of the pasture by the use of off-site watering, he is able to increase his forage production and have healthier livestock. He is able to generate a bigger return on investment and his business becomes more profitable.

The landowner in the above example now knows the true value of the BMP and is more likely to maintain this BMP, implement the BMP on some of his other pastures, and share his successes with friends and neighbors. The successful voluntary implementation of a BMP can spark interest by other landowners in the watershed to install similar practices.

Another good example of voluntary BMP implementation is the work that the US Forest Service has done on Meadow Creek in the Bitterroot headwaters area. Meadow Creek was first listed as impaired by sediment in 2006. Restoration activities and changes in grazing management practices in the Meadow Creek watershed triggered DEQ to re-assess the stream for sediment. Meadow Creek was re-assessed in 2013 and was found to be no longer impaired for sediment.

Stakeholders within the watershed are encouraged to develop a Watershed Restoration Plan (WRP) as described in **Section 9.3**. A WRP would serve as a locally organized “road map” for watershed activities, sequences of projects, prioritizing of projects, and funding sources for achieving local watershed goals, including water quality improvements.

In contrast to nonpoint source implementation, point sources are regulated through a permitting program, and point source discharges to surface water are given a wasteload allocation in the TMDL for impaired waterbodies. For example, in this particular document, the City of Lolo Wastewater Treatment Plant is given a wasteload allocation for lead in **Section 6.6.2**. Any wasteload allocations assigned to a particular point source discharge are taken into consideration during the upcoming permit renewal cycle, which is also defined in MCA section 75-5-703(6). The two permits that you mentioned in your above comment are regulated through the Montana Ground Water Pollution Control System (MGWPCS) and discharge normal residential-strength domestic waste to groundwater. The MGWPCS program, regulated through DEQ, issues discharge permits to protect state groundwaters. Wasteload allocations in the TMDL are only given to point source surface water discharges that require discharge permits under the Montana Pollutant Discharge Elimination System (MPDES) permit program.

As identified in the monitoring recommendation that you refer to, continued monitoring of the river and tributaries is encouraged to help identify new nonpoint sources and identify potential impacts from all sources. This monitoring could identify nutrient impacts from multiple nonpoint sources, whether related to groundwater or surface water pathways. Future monitoring could be focused in areas that are experiencing the highest growth and have greatest potential for nutrient loading.

3b. Thank you for your comment. Language in **Section 6.5.1** has been updated to encompass your suggestions.

12.0 References

Alban, J. 2012. The River Blog: The Hidden Life of Stormwater. http://www.clarkfork.org/?p=661&option=com_wordpress&Itemid=524.

Andrews, Edmund D. and James M. Nankervis. 1995. "Effective Discharge and the Design of Channel Maintenance Flows for Gravel-Bed Rivers: Natural and Anthropogenic Influences in Fluvial Geomorphology," in *Natural and Anthropogenic Influences in Fluvial Geomorphology: The Wolman Volume*, Costa, John E., Miller, Andrew J., Potter, Kenneth W., and Wilcock, Peter R. Geophysical Monograph Series, Ch. 10: American Geophysical Union): 151-164.

Baker, Joan P. and Carl L. Schofield. 1982. Aluminum Toxicity to Fish in Acidic Waters. *Water, Air, and Soil Pollution.* 18(1-3): 289-309.

Barbour, Michael T., Jeroen Gerritsen, Blaine D. Snyder, and James B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish: Second Edition. Washington, DC: United States Department of Environmental Protection, Office of Water. EPA 841-B-99-002.

Bear, Elizabeth A., Thomas E. McMahon, and Alexander V. Zale. 2007. Comparative Thermal Requirements of Westslope Cutthroat Trout and Rainbow Trout: Implications for Species Interactions and Development of Thermal Protection Standards. *Transactions of the American Fisheries Society.* 136: 1113-1121.

Brady, Nyle and Ray R. Weil. 2002. The Nature and Properties of Soil, 13th ed. ed., Pearson Education.

Brown, R. S. 1999. Fall and Early Winter Movements of Cutthroat Trout, Oncorhynchus Clarki, in Relation to Water Temperature and Ice Conditions in Dutch Creek, Alberta. *Environmental Biology of Fishes.* 55: 359-368.

Brown, R. S., S. S. Stanislawski, and William C. Mackay. 1993. The Effects of Frazil Ice on Fish. Prowse, T. D. Saskatoon, Saskatchewan: National Hydrology Research Institute. NHRI Symposium Series.

Buchman, Michael F. 1999. NOAA Screening Quick Reference Tables. NOAA HAZMAT Report 99-1. Seattle, WA: NOAA. http://response.restoration.noaa.gov/book_shelf/122_squirt_cards.pdf.

Buckler, Denny R., Paul M. Mehrle, Laverne Cleveland, and F. J. Dwyer. 1987. Influence of PH on the Toxicity of Aluminum and Other Inorganic Contaminants to East Coast Striped Bass. *Water, Air, and Soil Pollution.* 35(1-2): 97-106.

Cao, X., L. Ma, M. Chen, D. Hardison, and W. Harris. 2003. Lead Transformation and Distribution in the Soils of Shooting Ranges in Florida, USA. *The Science of the Total Environment.* 307 (2003): 179-189.

Carlons, C. E. and R. F. Floch. 1996. "Lick Creek Ecosystem Management/Research Demonstration Area," in *Experimental Forests, Ranges, and Watersheds in the Northern Rocky Mountains: A Compendium of Outdoor Laboratories in Utah, Idaho, and Montana*, General Technical Report INT-GR-334 ed., United States Department of Agriculture, Forest Service, Intermountain Research Station): 81.

Cleveland, Laverne, Edward E. Little, Steven J. Hamilton, Denny R. Buckler, and Joseph B. Hunn. 1986. Interactive Toxicity of Aluminum and Acidity to Early Life Stages of Brook Trout. *Transactions of the American Fisheries Society.* 115(4): 610-620.

Craig, J. R., J. D. Rimstidt, C. A. Bannaffon, T. K. Collins, and P. F. Scanlon. 1999. Surface Water Transport of Lead at a Shooting Range. *Bulletin of Environmental Contamination and Toxicology.* 63 (1999): 312-319.

Drygas, Jonathan. 2012. The Montana Department of Environmental Quality Metals Assessment Method.

Federal Register. 2013. Organic Arsenicals: Admendments to Terminate Uses; Amendment to Existing Stocks Provisions. *Federal Register.* 78 United States Federal Register 59 (27 March 2013: 18590-18591.

Feller, M. C. and J. P. Kimmins. 1984. Effects of Clearcutting and Slash Burning on Streamwater Chemistry and Watershed Nutrient Budgets in Southwestern British Columbia. *Water Resources Research.* 20: 29-40.

Geospatial Multi-Agency Coordination Group. 2014. 2000_Perimeters_Dd83. http://rmgsc.cr.usgs.gov/outgoing/GeoMAC/historic_fire_data/2000_perimeters_dd83.zip. Accessed 3/5/2014.

Geosyntec Consultants, Inc. and Wright Water Engineers, Inc. 2012. International Stormwater Best Management Practices (BMP) Database Pollutant Category Summary Statistical Addendum: TSS, Bacteria, Nutrients, and Metals.

Gibson, C. E. and P. Morgan. 2009. Atlas of Digital Polygon Fire Extents for Idaho and Western Montana (1889-2003). Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. http://www.fs.usda.gov/rds/archive/data/open/rds-2009-0006/rds-2009-006.aspx.

Green, Douglas M. and J. B. Kauffman. 1989. "Nutrient Cycling at the Land-Water Interface: The Importance of the Riparian Zone," in *Practical Approaches to Riparian Resource Management: An Education Workshop*, Gresswell, Robert E., Barton, Bruce A., and Kershner, Jeffrey L., (Billings, MT: U.S. Bureau of Land Management): 61-68.

Gruell, George E., Wyman C. Schmidt, Stephen F. Arno, and William J. Reich. 1982. Seventy Years of Vegetative Change in Managed Ponderosa Pine Forest in Western Montana - Implications for Resource Management. Odgen UT: U.S. Department of Agrigulture, Forest Service, Intermountain Forest and Range Experiment Station. General Technical Report INT-130. http://www.fs.fed.us/rm/pubs/rmrs_gtr292/int_gtr130.pdf.

Grumbles, Benjamin. 2006. Letter From Benjamin Grumbles, US EPA, to All EPA Regions Regarding Dail Load Development. U.S. Environmental Protection Agency.

Hargrave, Phyllis A., Mike D. Kerschen, C. McDonald, John J. Metesh, and Robert Wintergerst. 2003. Abandoned-Inactive Mines on Lolo National Forest Administered Lands. Open-File Report 476.

Harmon, Will. 1999. Best Management Practices (BMPs) for Grazing: Montana. Helena, MT: Conservation Districts Bureau, Department of Natural Resources and Conservation.

Hewlett, John D. and J. C. Fortson. 1982. Stream Temperature Under an Inadequate Buffer Strip in the Southeast Piedmont. *Water Resources Bulletin.* 18: 983-988.

Hooten, Daniel A. 1999. Non-Point Nutrient and Sediment Assessment Project in a Portion of the Bitterroot River Drainage. Hamilton, MT: Ravalli County Sanitarian's Office.

Howell, M. 2005. USFWS to Fund Study of Car Rip Rap. *Bitterroot Star*

Howell, Terry A. and B. A. Stewart. 2003. "Irrigation Efficiency," in *Encyclopedia of Water Science*, (New York, NY: Marcel Dekker): 467-472.

Hunn, Joseph B., Laverne Cleveland, and Edward E. Little. 1987. Influence of PH and Aluminum on Developing Brook Trout in a Low Calcium Water. *Environmental Pollution.* 43(1): 63-73.

Jacobson, R. B. 2004. Downstream Effects of Timber Harvest in the Ozarks of Missouri. *Toward Sustainability For Missouri Forests.*: 106-1260.

Jakober, Michael J., Thomas E. McMahon, Russell F. Thurow, and Christopher C. Clancy. 1998. Role of Stream Ice on Fall and Winter Movements and Habitat Use by Bull Trout and Cutthroat Trout in Montana Headwater Streams. *Transactions of the American Fisheries Society.* 127: 223-235.

Jorgensen, S. S. and M. Willems. 1987. The Fate of Lead in Soils: The Transformation of Lead Pellets in Shooting-Range Soils. *AMBIO: A Journal of the Human Environment.* 1987: 11-15.

Kannan, N., J. Jeong, and R. Srinivasan. 2011. Hydrologic Modeling of a Canal-Irrigated Agricultrual Watershed With Irrigation Best Management Practices. *Journal of Hydrologic Engineering.*: 746-757.

Lakel, William A. I., Wallace M. Aust, M. C. Bolding, C. A. Dolloff, Patrick Keyser, and Robert Feldt. 2010. Sediment Trapping by Streamside Management Zones of Various Widths After Forest Harvest and Site Preparation. *Forest Science.* 56(6): 541-5.

Lee, Ki H., T. M. Isenhart, and R. C. Schultz. 2003. Sediment and Nutrient Removal in an Established Multi-Species Riparian Buffer. *Journal of Soil and Water Conservation.* 58(1): 1-8.

Lide, David R. 2005. CRC Handbook of Chemistry and Physics, Internet Version 2005. Boca Raton, FL: CRC Press. http://www.hbcpnetbase.com.

Likens, Gene E., F. H. Bormann, Robert S. Pierce, and W. A. Reiners. 1978. Recovery of a Deforested Ecosystem. *Science.* 199(4328): 492-496.

Lines, G. and P. Graham. 1988. Westslope Cutthroat Trout in Montana: Life History, Status and Management. In: Montana American Fisheries Society Symposium. 53-60.

Martin, C. W. and R. D. Harr. 1989. Logging of Mature Douglas-Fir in Western Oregon Has Little Effect on Nutrient Output Budgets. *Canadian Journal of Forest Research.* 19(1): 35-43.

Mayer, Paul M., Steven K. Reynolds, Jr., Timothy J. Canfield, and Marshall D. McCutchen. 2005. Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations. Cincinnati, OH: National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency. EPA/600/R-15/118.

McCullough, Dale and Shelley Spalding. 2002. Multiple Lines of Evidence for Determining Upper Optimal Temperature Thresholds for Bull Trout. S.l.: s.n.

McDowell, Will and Jim Rokosch. 2005. Ambrose-Threemile Watershed Project: Watershed Assessment and Recommendations for Stream Improvements. Sandpoint, ID: Tri-State Water Quality Council.

Missoula City-County Health Department and Missoula Valley Water Quality District. 1997. Storm and Ground Water Quality Impacts of Chemical Deicer Usage in Missoula, Montana. MT: Missoula City-County Health Department and Missoula Valley Water Quality District for the Montana Department of Environmental Quality.

Montana Department of Environmental Quality. 1997. Data Search Tools, Unpermitted Releases Dataset. Fort Missoula OMS 2. http://svc.mt.gov/deq/olqs/srs/report.aspx?site=moms#. Accessed 3/17/2014.

-----. 2002. Data Search Tools, Unpermitted Releases Dataset. Missoula Vocational Tech Center and Missoula Technology and Development Center. http://svc.mt.gov/deq/olqs/srs/query.aspx. Accessed 3/17/2014.

-----. 2005a. Field Procedures Manual For Water Quality Assessment Monitoring. Helena, MT: Montana Department of Environmental Quality, Water Quality Planning Bureau. WQPBWQM-020.

-----. 2005b. Temperature Data Logger Protocols Standard Operating Procedure. WQPBWQM-006, Rev. 1. http://www.deq.mt.gov/wqinfo/QAProgram/PDF/SOPs/WQPBWQM-006.pdf.

-----. 2009a. Abandoned Mine Information: Historical Narratives. http://www.deq.mt.gov/abandonedmines/linkdocs/default.mcpx.

-----. 2009b. How to Perform a Nondegradation Analysis for Subsurface Wastewater Treatment Systems (SWTS) Under the Subdivision Review Process. Helena, MT: Montana Department of Environmental Quality.

-----. 2011. The Missouri-Cascade and Belt TMDL Planning Area: Metals Total Maximum Daily Loads and Framework Water Quality Improvement Plan. Helena, MT: Montana Department of Environmental Quality. M12-TMDL-02a-F.

-----. 2012. Circular DEQ-7: Montana Numeric Water Quality Standards. Helena, MT: Montana Department of Environmental Quality. http://deq.mt.gov/wqinfo/Circulars.mcpx. Accessed 1/15/2013.

-----. 2013. Rock Creek Watershed Total Maximum Daily Loads and Water Quality Improvement Plans - Final. C02-TMDL-02aF. http://deq.mt.gov/wqinfo/TMDL/finalReports.mcpx. Accessed 10/21/2014.

-----. 2014a. Final Silver Bow Creek and Clark Fork River Metals TMDLs. Helena, MT: =Montana Department of Environmental Quality. C01-TMDL-05aF.

-----. 2014b. Montana Underground Storage Tank Facilities April 29, 2014. Montana Department of Environmental Quality, Waste and Underground Tank Management Bureau. Underground Storage Tank - Leak Prevention Program. http://deq.mt.gov/ust/monthlyreportspdf/ustlist.pdf. Accessed 5/27/2014b.

-----. 2014c. Montana UST Facility Operating Permit Status. Montana Department of Environmental Quality, Waste and Underground Tank Management Bureau. Underground Storage Tank - Leak Prevention Program. http://www.deq.mt.gov/ust/monthlyreportspdf/ustfacilityoperatingpermitstatus.pdf. Accessed 5/27/2014c.

-----. 2014d. Water Quality Assessment Database. Helena, MT: Montana Department of Environmental Quality. http://deq.mt.gov/wqinfo/CWAIC/default.mcpx. Accessed 8/18/2014d.

Montana Department of Environmental Quality and U.S. Environmental Protection Agency. 2013. Lake Helena Planning Area Metals TMDL Addendum. Helena, MT.

-----. 2014. Little Blackfoot River Watershed TMDLs and Framework Water Quality Improvement Plan - Metals Addendum. Helena, MT: Montana Department of Environmental Quality.

Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau. 2011a. Bitterroot Temperature and Tributary Sediment Total Maximum Daily Loads and Framework Water Quality Improvement Plan: Final. Helena, MT: Montana Department of Environmental Quality. C05-TMDL-03aF.

-----. 2011b. Water Quality Assessment Method. Helena, MT: Montana Department of Environmental Quality. Revision 3.0.

-----. 2012a. Flint Creek Planning Area Sediment and Metals TMDLs and Framework Water Quality Improvement Plan. CO2-TMDL-01aF.

-----. 2012b. Montana 2012 Final Water Quality Integrated Report. Helena, MT: Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau. WQPBIMTSR-004f.

-----. 2012c. Montana's Nonpoint Source Management Plan. Helena, MT: Montana Department of Environmental Quality, Water Quality Planning Bureau, Watershed Protection Section. WQPBWPSTR-005.

-----. 2014. Montana 2014 Final Water Quality Integrated Report. Helena, MT: Montana Department of Environmental Quality. WQPBIMTSTR-009d.

Montana Department of Fish, Wildlife and Parks. 2014. Montana's Fisheries Information System (MFISH). http://fwp.mt.gov/fishing/mFish/. Accessed 2/20/2013.

Montana Department of Natural Resources and Conservation. 2010. Forested State Trust Lands Final EIS Appendix A Habitat Conservation Plan. Missoula, MT. http://dnrc.mt.gov/hcp/finaleis.asp.

Montana Department of Public Health and Human Services, Montana Department of Environmental Quality, and Wildlife and Parks Montana Department of Fish. 2014. Montana Sport Fish Consumption Guidelines. Helena, MT: Montana Department of Public Health and Human Services, Montana Fish, Wildlife and Parks, and Montana Department of Environmental Quality. http://fwp.mt.gov/fwpDoc.html?id=28187.

Montana Fish, Wildlife and Parks. 2013. Fishing Restrictions Lifted on the Bitterroot. http://fwp.mt.gov/news/newsReleases/drought/nr_0132.html. Accessed 7/29/2014.

Montana Mines and Geology. 2013. Groundwater Information System. http://mbmggwic.mtech.edu.

Montana Natural Heritage Program. 2001. Western Montana Ecoregion Descriptions. http://nhguide.dbs.umt.edu/index.php?c=habitats&m=wmt_ecoregions_desc. Accessed 7/28/2014.

Montana Natural Heritage Program and Montana Fish, Wildlife and Parks. 2013. Westslope Cutthroat Trout - Oncorhynchus Clarkia Lewisi. Montana Field Guide. Helena, MT: Montana Natural Heritage Program. http://fieldguide.mt.gov/detail_AFCHA02088.aspx. Accessed 3/11/2014.

-----. 2014. Yellowstone Cutthroat Trout - Oncorhynchus Clarkii Bouvieri. Montana Field Guide. Helena, MT: Montana Natural Heritage Program. http://fieldguide.mt.gov/detail_AFCHA02087.aspx. Accessed 7/28/2014.

Montana State University Extension Service. 2001. Water Quality BMPs for Montana Forests. Bozeman, MT: MSU Extension Publications.

Natural Resources Conservation Service. 1997. National Engineering Handbook Irrigation Guide, Vol. Part 652, Washington, D.C.: Natural Resources Conservation Service.

Nature Education. 2013. The Nature Education Knowledge Project: Restoration Ecology. http://www.nature.com/scitable/knowledge/library/restoration-ecology-13339059.

Negri, Donald and D. H. Brooks. 1990. Determinants of Irrigation Technology Choice. *Western Journal of Agricultural Economics.* 15: 213-223.

Negri, Donald, John J Hanchar, and U.S. Department of Agriculture, Economic Research Service. 1989. Water Conservation Through Irrigation Technology. Washington, D.C.: Economic Research Service. AIB-576.

Osteen, C., J. Gottlieb, and U. Vasavada. 2012. Agricultural Resources and Environmental Indicators. Washington, D.C.: United States Department of Agriculture, Economic Research Service. EIB-98.

Pioneer Technical Services, Inc. 1995. Abandoned Hardrock Mine Priority Sites: 1995 Summary Report, Butte, MT: Pioneer Technical Services.

Plum Creek Timber Co. 2000. Final Plum Creek Timber Company Native Fish Habitat Conservation Plan. S.l.: Plum Creek Timber Company.

Poole, Geoffrey C. and Cara H. Berman. 2001. An Ecological Perspective on In-Stream Temperature: Natural Heat Dynamics and Mechanisms of Human-Caused Thermal Degradation. *Environmental Management.* 276(6): 787-802.

Priscu, John C. 1987. Environmental Factors Regulating the Dynamics of Blue-Green Algal Blooms in Canyon Ferry Reservoir, Montana. Bozeman, MT: Montana Water Resources Research Institute. Report # 159.

PRISM Climate Group. 2013. Monthly Average Annual Precipitation, 1981-2010.

Raines, Gary L and Bruce R. Johnson. 1995. Digital Representation of the Montana State Geologic Map in ARC/INFO Export Format. http://pubs.usgs.gov/of/1995/ofr-95-0691/.

-----. 1996. Digital Representation of the Montana State Geologic Map: a Contribution to the Interior Columbia River Basin Ecosystem Management Project. USGS. USGS Open File Report 95-691.

Reeves, Marie. 2001. Curlew Mine Tailings Pond Area Reclamation Project. Reclamation Research Unit, Montana State University. Montana Department of Environmental Quality. http://www.ecorestoration.montana.edu/mineland/histories/metal/curlew/default.htm.

Schmidt, Larry J. and John P. Potyondy. 2004. Quantifying Channel Maintenance Instream Flows: An Approach for Gravel-Bed Streams in the Western United States. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. General Technical Report RMRS-GTR-128.

Selong, Jason H., Thomas E. McMahon, Alexander V. Zale, and Frederic T. Barrows. 2001. Effect of Temperature on Growth and Survival of Bull Trout, With Application of an Improved Method for Determining Thermal Tolerance in Fishes. *Transactions of the American Fisheries Society.* 130: 1026-1037.

Suplee, Michael W. 2013. Technical Memorandum: Benchmark for Nitrate + Nitrite in Assessing Ambient Surface Water. McCarthy, Mindy and Eric Urban.

Suplee, Michael W. and Rosie Sada de Suplee. 2011. Assessment Methodology for Determining Wadeable Stream Impairment Due to Excess Nitrogen and Phosphorus Levels. Helena, MT: Montana Department of Environmental Quality Water Quality Planning Bureau. WQPMASTR-01.

Suplee, Michael W., Arun Varghese, and Joshua Cleland. 2007. Developing Nutrient Criteria for Streams: An Evaluation of the Frequency Distribution Method. *Journal of the American Water Resources Association.* 43(2): 453-472.

Suplee, Michael W. and Vicki Watson. 2013. Scientific and Technical Basis of the Numeric Nutrient Criteria for Montana's Wadeable Streams and Rivers—Update 1. Helena, MT: Montana Department of Environmental Quality.

Suplee, Michael W., Vicki Watson, Mark E. Teply, and Heather McKee. 2009. How Green Is Too Green? Public Opinion of What Constitutes Undesirable Algae Levels in Streams. *Journal of the American Water Resources Association.* 45(1): 123-140.

Suplee, Michael W., Vicki Watson, Arun Varghese, and Joshua Cleland. 2008. Scientific and Technical Basis of the Numeric Nutrient Criteria for Montana's Wadeable Streams and Rivers. Helena, MT: Montana Department of Environmental Quality.

Sylte, Traci and Jennifer Mickelson. 2008. Watershed Improvement Tracking Lolo National Forest - Executive Summary. Missoula, MT: Lolo National Forest. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm9_021397.pdf.

Tetra Tech. 2013. Mill Creek and White Pine Creek Temperature Modeling: Ssampling Analysis Plan and Quality Assurance Project Plan. U.S. EPA. QAPP 370.

U.S. Bureau of Reclamation. 2009. Lead Fact Sheet, National Primary Drinking Water Regulations. U.S. Department of Interior, Bureau of Reclamation. http://www.usbr.gov/pmts.water/publications/reportpdfs/primer%20files/08%20-%20lead.pdf. Accessed 3/1/2014.

U.S. Department of Agriculture, Forest Service, Bitterroot National Forest. 1987. Bitterroot National Forest: Forest Plan. Hamilton, MT: United States Department of Agriculture, Forest Service, Northern Region.

U.S. Environmental Protection Agency. 1988. Ambient Water Quality Criteria for Aluminum. Washington, DC: U.S. Environmental Protection Agency, Offiece of Water Regulations and Standards Criteria and Standards Division. EPA 440/5-86-008.

-----. 1999. Protocol for Developing Nutrient TMDLs. Washington, D.C.: Office of Water, U.S. Environmental Protection Agency. EPA 841-B-99-007.

-----. 2002. Memorandum: Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs. U.S. Environmental Protection Agency.

-----. 2003. TRW Recommendations for Performing Human Health Risk Analysis on Small Arms Shooting Ranges. Washington, D.C.: Office of Solid Waste and Emergency Response. OSWER #9285.7-37. http://www.epa.gov/superfund/lead/products/firing.pdf.

-----. 2010. Using Stressor-Response Relationships to Derive Numeric Nutrient Criteria. Washington, DC: Office of Science and Technology, Office of Water, EPA. EPA-820-S-10-001.

-----. 2014. Technical Factsheet on: LEAD. U.S. Environmental Protection Agency. http://www.epa.gov/ogwdw/pdfs/factsheets/ioc/tech/lead.pdf. Accessed 4/1/2014.

U.S. Forest Service. 2013. Lick Creek Demonstration/Rsearch Forest Interpretive Auto Tour Bitterroot National Forest. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5143508.pdf. Accessed 2/1/2014.

U.S. Geological Survey. 2013. GeoMAC Wildland Fire Support Geospatial Multi-Agency Coordination. U.S. Geological Survey. http://www.geomac.gov/index.shtml. Accessed 10/25/2013.

U.S. Geological Survey and U.S. Environmental Protection Agency. 2014. Water Quality Portal. http://www.waterqualitydata.us/index.jsp.

United States Census Bureau. 2014. State and County QuickFacts, Ravalli County, Montana. http://quickfacts.census.gov/qfd/states/30/30081.html. Accessed 7/28/2014.

United States Department of Agriculture, Natural Resources Conservation Service. 2005. Natural Resources Conservation Service Conservation Practice Standard: Nutrient Management (Acre), Code 590. http://efotg.sc.egov.usda.gov/references/public/wi/590.pdf. Accessed 3/31/2014.

-----. 2010. Natural Resources Conservation Service Conservation Practice Standard: Prescribed Grazing (Ac), Code 528. http://efotg.sc.egov.usda.gov/references/public/ne/ne528.pdf. Accessed 3/31/2014.

United States Forest Service. 1986. The Lolo National Forest Plan. http://www.fs.usda.gov/internet/fse_documents/stelprdb5299100.pdf.

Waskom, Reagan M. 1994. Best Management Practices for Irrigation Management. Colorado State University Coorperative Extension Office.

Wegner, Seth. 1999. A Review of the Scientific Literature on Riparian Buffers Width, Extent and Vegetation. Institute of Ecology, University of Georgia.

Wischmeier, Walter H. and Dwight D. Smith. 1978. Predicting Rainfall Erosion Losses: A Guide to Conservation Planning. Washington, D.C.: United States Department of Agriculture. Agriculture Handbook No. 537. http://topsoil.nserl.purdue.edu/usle/AH_537.pdf.

Woods, Alan J., James M. Omernik, John A. Nesser, Jennifer Shelden, Jeffrey A. Comstock, and Sandra J. Azevedo. 2002. Ecoregions of Montana, 2nd ed., Reston, VA: United States Geographical Survey.

World Health Organization. 2003a. Aluminum in Drinking Water Background Document for Development of WHO Guidelines for Drinking-Water Quality. Geneva, Switzerland: World Health Organization. http://www.who.int/water_sanitation_health/dwq/chemicals/en/aluminium.pdf. Accessed 3/1/2014a.

-----. 2003b. Guidelines for Safe Recreational Water Environments, Volume 1: Coastal and Fresh Waters. Geneva, Switzerland: World Health Organization. http://www.who.int/water_sanitation_health/bathing/srwe1/en/.

APPENDIX A – TABLES AND FIGURES

LIST OF TABLES

LIST OF FIGURES

Table A-1. Status of waterbody impairments in the TMDL planning areas within the Bitterroot watershed, based on the 2014 Integrated Report

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category	Impairment Cause Status *
[1]**Ambrose Creek**, headwaters to mouth (Threemile Creek)	MT76H004_120	Nitrogen (Total)	Nutrients	Addressed by a TN TMDL in this document
		Phosphorus (Total)	Nutrients	Addressed by a TP TMDL in this document
		Physical substrate habitat alterations	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2011)
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2011)
[1]**Bass Creek**, Selway-Bitterroot Wilderness boundary to mouth (un-named channel of Bitterroot River)	MT76H004_010	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in Section 8 of this document
		Nitrogen (Total)	Nutrients	Addressed by a TN TMDL in this document
		Phosphorus (Total)	Nutrients	Addressed by a TP TMDL in this document
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2011)
[1]**Bear Creek**, Selway-Bitterroot Wilderness boundary to mouth (Fred Burr Creek)	MT76H004_031	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in Section 8 of this document
[1]**Bitterroot River**, East and West forks to Skalkaho Creek	MT76H001_010	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed in Section 8 of this document
[1]**Bitterroot River**, Skalkaho Creek to Eightmile Creek	MT76H001_020	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in Section 8 of this document
		Sedimentation/Siltation	Sediment	Not impaired based on updated assessment
		Temperature, water	Temperature	Addressed by a temperature TMDL in a previous document (2011)
[1]**Bitterroot River**, Eightmile Creek to mouth (Clark Fork River)	MT76H001_030	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a temperature TMDL in a previous document (2011)
		Lead	Metals	Addressed by a lead TMDL in this document
		Sedimentation/Siltation	Sediment	Not impaired based on updated assessment
		Temperature, water	Temperature	Addressed by a temperature TMDL in a previous document (2011)
[1]**Blodgett Creek**, Selway-Bitterroot Wilderness boundary to mouth (Bitterroot River)	MT76H004_050	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in Section 8 of this document
[2]**Buck Creek**, headwaters to mouth (West Fork Bitterroot)	MT76H003_070	Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2005)

Table A-1. Status of waterbody impairments in the TMDL planning areas within the Bitterroot watershed, based on the 2014 Integrated Report

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category	Impairment Cause Status *
[2]**Ditch Creek**, headwaters to mouth (West Fork Bitterroot River)	MT76H003_060	Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2005)
[2]**East Fork Bitterroot River**, Anaconda-Pintlar Wilderness boundary to mouth (Bitterroot River)	MT76H002_010	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2005)
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2005)
		Temperature, water	Temperature	Addressed by a temperature TMDL in a previous document (2005)
[3]**East Fork Lolo Creek**, headwaters to mouth (Confluence with Lolo Creek)	MT76H005_040	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2003)
		Fish-Passage Barrier	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2003)
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2003)
[2]**Gilbert Creek**, headwaters to mouth (Laird Creek)	MT76H002_080	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2005)
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2005)
[3]**Granite Creek**, headwaters to mouth (Lolo Creek)	MT76H005_030	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2003)
		Fish-Passage Barrier	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2003)
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2003)
[2]**Hughes Creek**, headwaters to the mouth (West Fork Bitterroot River)	MT76H003_040	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2005)
		Physical substrate habitat alterations	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2005)
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2005)
		Temperature, water	Temperature	Addressed by a temperature TMDL in a previous document (2005)

Table A-1. Status of waterbody impairments in the TMDL planning areas within the Bitterroot watershed, based on the 2014 Integrated Report

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category	Impairment Cause Status *
[1]**Kootenai Creek**, Selway-Bitterroot Wilderness boundary to mouth (Bitterroot River)	MT76H004_020	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed in Section 8 of this document
		Low flow alterations	Not Applicable; Non-Pollutant	Addressed in section 8 of this document
[2]**Laird Creek**, headwaters to mouth (East Fork Bitterroot River)	MT76H002_070	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2005)
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2005)
[3]**Lee Creek**, headwaters to mouth (West Fork Lolo Creek)	MT76H005_070	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2003)
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2003)
[1]**Lick Creek**, headwaters to mouth (Bitterroot River)	MT76H004_170	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2011)
		Aluminum	Metals	Addressed by an aluminum TMDL in this document
		Chlorophyll-a	Not Applicable; Non-Pollutant	Addressed by a TP TMDL in this document
		Phosphorus (Total)	Nutrients	Addressed by a TP TMDL in this document
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2011)
[1]**Lolo Creek**, Mormon Creek to mouth (Bitterroot River)	MT76H005_011	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in Section 8 of this document
		Physical substrate habitat alterations	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2011)
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2011)
[1]**Lolo Creek**, Sheldon Creek to Mormon Creek	MT76H005_012	Physical substrate habitat alterations	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2011)
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2011)

Table A-1. Status of waterbody impairments in the TMDL planning areas within the Bitterroot watershed, based on the 2014 Integrated Report

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category	Impairment Cause Status *
[1]**Lolo Creek**, headwaters to Sheldon Creek	MT76H005_013	Physical substrate habitat alterations	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2011)
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2011)
[1]**Lost Horse Creek**, headwaters to mouth (Bitterroot River)	MT76H004_070	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in Section 8 of this document
[3]**Lost Park Creek**, headwaters to mouth (Confluence with East Fork Lolo Creek)	MT76H005_060	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2003)
		Fish-Passage Barrier	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2003)
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2003)
[1]**McClain Creek**, headwaters to mouth (Sin-tin-tin-em-ska Creek)	MT76H004_150	Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2011)
[1]**Mill Creek**, Selway-Bitterroot Wilderness boundary to the mouth (Fred Burr Creek)	MT76H004_040	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a temperature TMDL in this document
		Low flow alterations	Not Applicable; Non-Pollutant	Addressed in Section 8 of this document
		Temperature, water	Temperature	Addressed by a temperature TMDL in this document
[1]**Miller Creek**, headwaters to mouth (Bitterroot River)	MT76H004_130	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2011)
		Chlorophyll-a	Not Applicable; Non-Pollutant	Not impaired based on updated assessment
		Nitrate/Nitrite (Nitrite + Nitrate as N)	Nutrients	Not impaired based on updated assessment
		Nitrogen (Total)	Nutrients	Not impaired based on updated assessment
		Phosphorus (Total)	Nutrients	Not impaired based on updated assessment
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2011)
		Temperature, water	Temperature	Addressed by a temperature TMDL in a previous document (2011)

Table A-1. Status of waterbody impairments in the TMDL planning areas within the Bitterroot watershed, based on the 2014 Integrated Report

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category	Impairment Cause Status *
[1]**Muddy Spring Creek**, headwaters to mouth (Gold Creek)	MT76H004_180	Nitrate/Nitrite (Nitrite + Nitrate as N)	Nutrients	Addressed by a NO_2 + NO_3 TMDL in this document
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2011)
[2]**Nez Perce Fork Bitterroot River**, headwaters to mouth (West Fork Bitterroot River)	MT76H003_020	Temperature, water	Temperature	Addressed by a temperature TMDL in a previous document (2005)
[1]**North Burnt Fork Creek**, confluence with South Burnt Fork Creek to Mouth (Bitterroot River)	MT76H004_200	Bottom Deposits	Sediment	Addressed by a sediment TMDL in a previous document (2011)
		Nitrogen (Total)	Nutrients	Addressed by a TN TMDL in this document
		Phosphorus (Total)	Nutrients	Addressed by a TP TMDL in this document
[1]**North Channel Bear Creek**, headwaters to mouth (Fred Burr Creek)	MT76H004_032	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in Section 8 of this document
[1]**North Fork Rye Creek**, headwaters to mouth (Rye Creek-Bitterroot River, South of Darby)	MT76H004_160	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by TN and TP TMDLs in this document
		Nitrogen (Total)	Nutrients	Addressed by a TN TMDL in this document
		Phosphorus (Total)	Nutrients	Addressed by a TP TMDL in this document
[2]**Overwhich Creek**, headwaters to mouth (West Fork Bitterroot River)	MT76H003_050	Temperature, water	Temperature	Addressed by a temperature TMDL in a previous document (2005)
[2]**Reimel Creek**, headwaters to mouth (East Fork Bitterroot River)	MT76H002_020	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2005)
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2005)
[1]**Rye Creek**, North Fork to mouth (Bitterroot River)	MT76H004_190	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2011)
		Nitrogen (Total)	Nutrients	Addressed by a TN TMDL in this document
		Phosphorus (Total)	Nutrients	Addressed by a TP TMDL in this document
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2011)
[1]**Skalkaho Creek**, headwaters to mouth (Bitterroot River)	MT76H004_100	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in Section 8 of this document

Table A-1. Status of waterbody impairments in the TMDL planning areas within the Bitterroot watershed, based on the 2014 Integrated Report

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category	Impairment Cause Status *
[1]**Sleeping Child Creek**, headwaters to mouth (Bitterroot River)	MT76H004_090	Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2011)
		Temperature, water	Temperature	Addressed by a temperature TMDL in a previous document (2011)
[1]**South Fork Lolo Creek**, Selway-Bitterroot Wilderness boundary to mouth (Lolo Creek)	MT76H005_020	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in Section 8 of this document
		Physical substrate habitat alterations	Not Applicable; Non-Pollutant	Addressed in Section 8 of this document
[1]**Sweathouse Creek**, headwaters to mouth (Bitterroot River)	MT76H004_210	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2011)
		Low flow alterations	Not Applicable; Non-Pollutant	Addressed in Section 8 of this document
		Phosphorus (Total)	Nutrients	Addressed by a TP TMDL in this document
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2011)
[1]**Threemile Creek**, headwaters to mouth (Bitterroot River)	MT76H004_140	Low flow alterations	Not Applicable; Non-Pollutant	Addressed in Section 8 of this document
		Nitrate/Nitrite (Nitrite + Nitrate as N)	Nutrients	Addressed by a TN TMDL in this document
		Nitrogen (Total)	Nutrients	Addressed by a TN TMDL in this document
		Phosphorus (Total)	Nutrients	Addressed by a TP TMDL in this document
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2011)
[1]**Tin Cup Creek**, Selway-Bitterroot Wilderness boundary to mouth (Bitteroot River)	MT76H004_080	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed in Section 8 of this document
[2]**West Fork Bitterroot River**, headwaters to mouth	MT76H003_010	Physical substrate habitat alterations	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2005)
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2005)
		Temperature, water	Temperature	Addressed by a temperature TMDL in a previous document (2005)

Table A-1. Status of waterbody impairments in the TMDL planning areas within the Bitterroot watershed, based on the 2014 Integrated Report

Waterbody & Location Description	Waterbody ID	Impairment Cause	TMDL Pollutant Category	Impairment Cause Status *
[3]**West Fork Lolo Creek**, headwaters to mouth (Lolo Creek)	MT76H005_050	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2003)
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2003)
[1]**Willow Creek**, headwaters to mouth (Bitterroot River)	MT76H004_110	Alteration in stream-side or littoral vegetative covers	Not Applicable; Non-Pollutant	Addressed by a sediment TMDL in a previous document (2011)
		Sedimentation/Siltation	Sediment	Addressed by a sediment TMDL in a previous document (2011)
		Temperature, water	Temperature	Addressed by a temperature TMDL in a previous document (2011)

* TN = Total Nitrogen, TP = Total Phosphorus, NO_2 + NO_3 = Nitrite + Nitrate
[1]Waterbody is part of the Bitterroot TPA, [2]Waterbody is part of the Bitterroot Headwaters TPA, [3]Waterbody is part of the Upper Lolo TPA

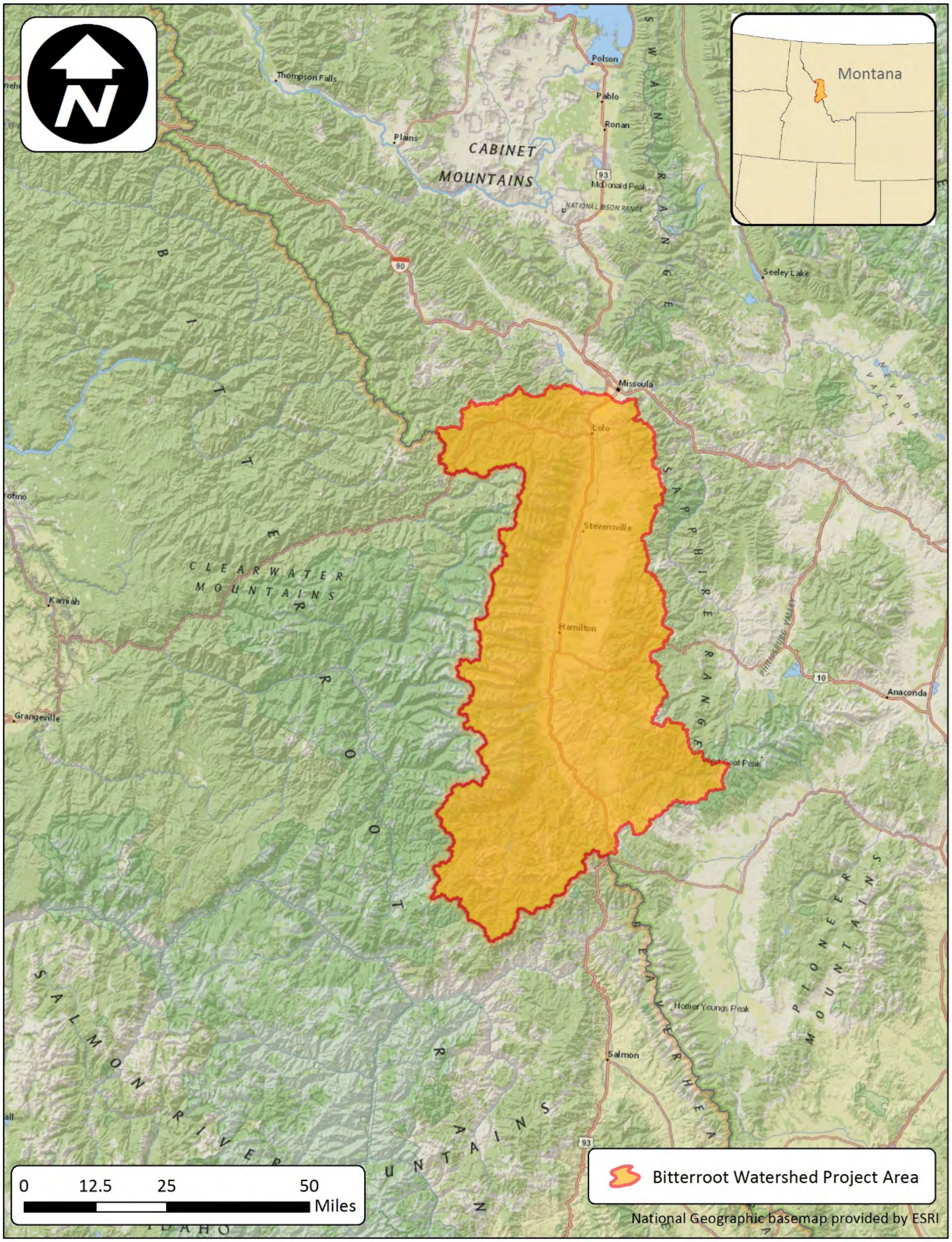


Figure A-1. Location of Bitterroot Watershed Project Area

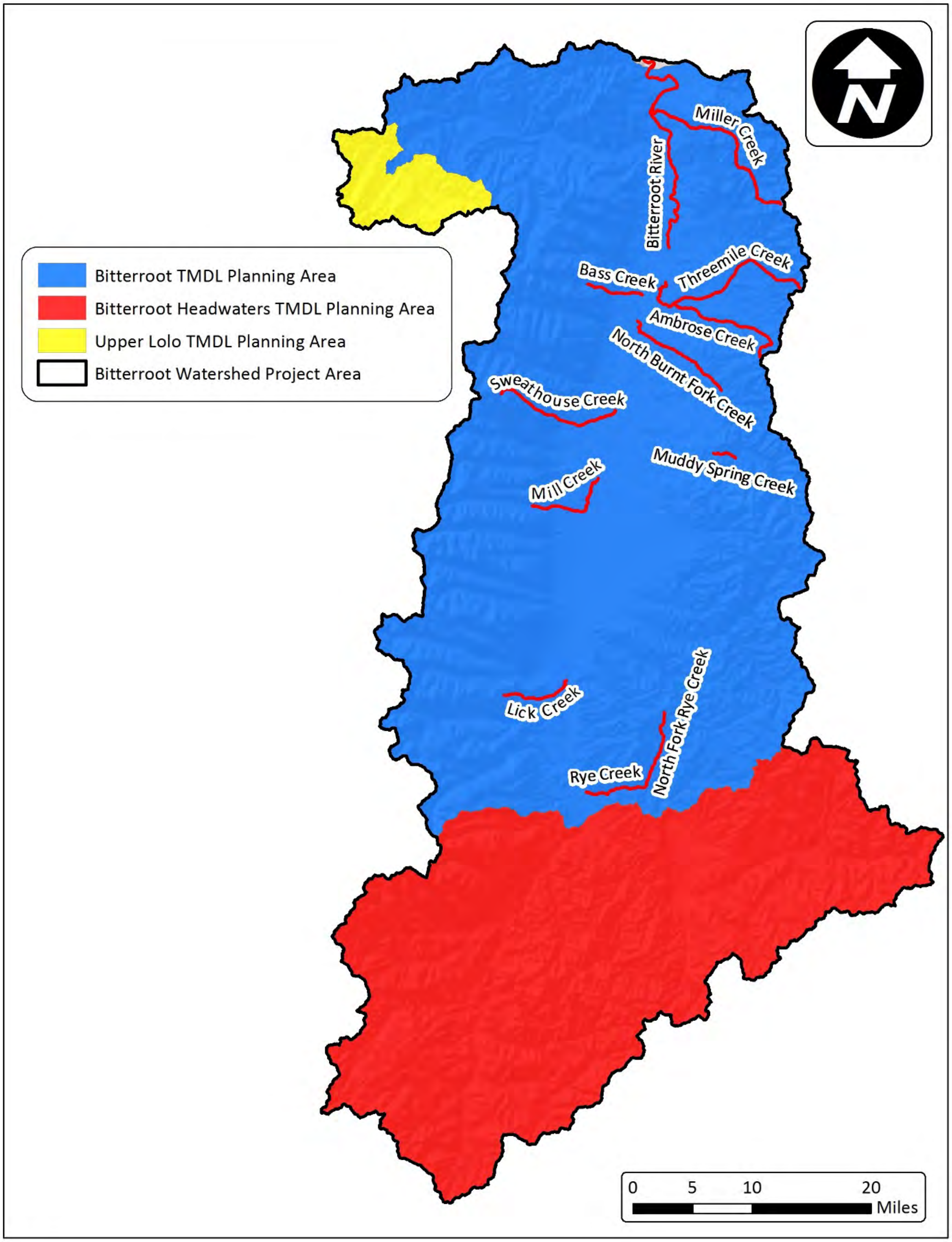


Figure A-2. TMDL Planning Areas (TPAs) within the Bitterroot Watershed Project Area

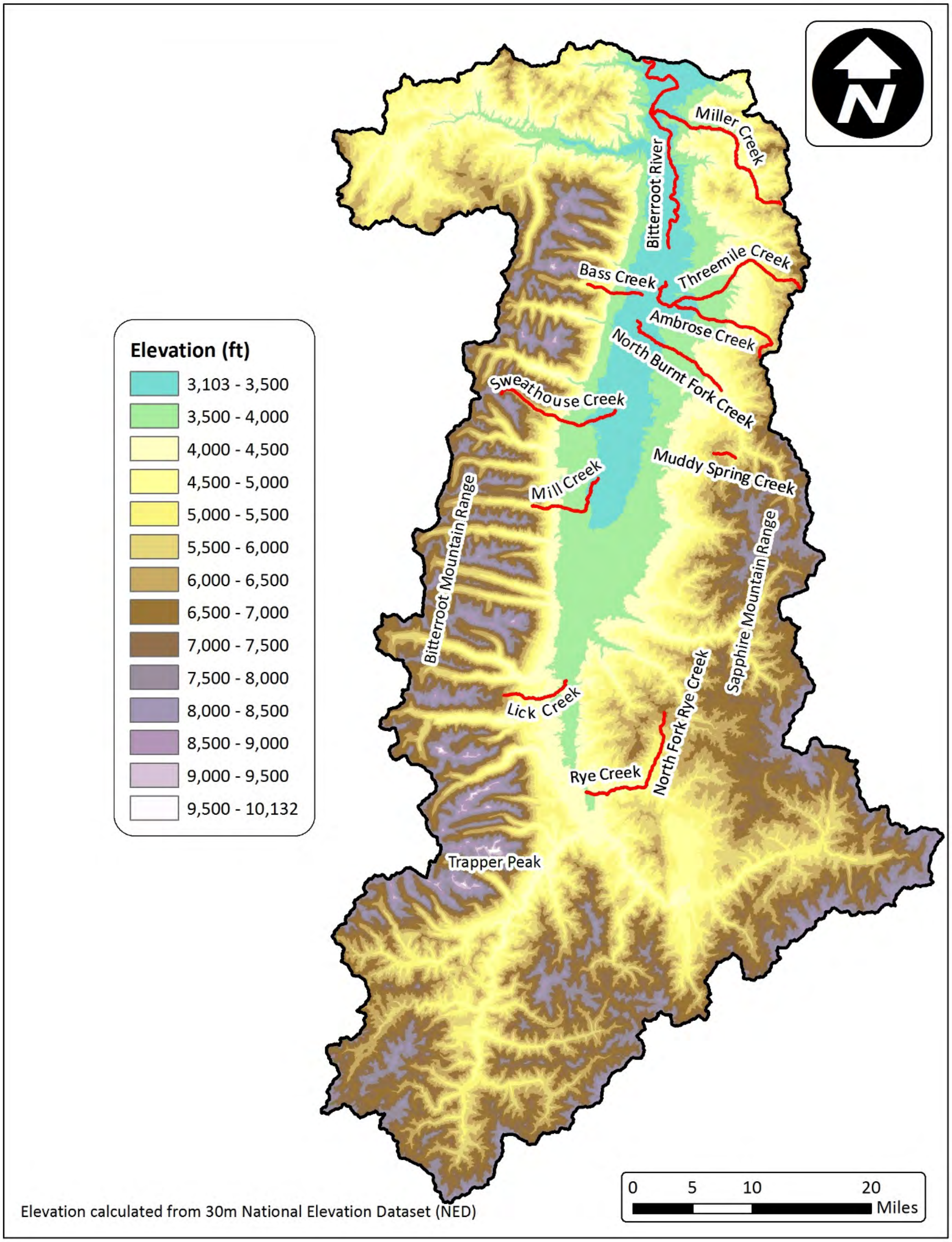


Figure A-3. Elevation of the Bitterroot Watershed Project Area

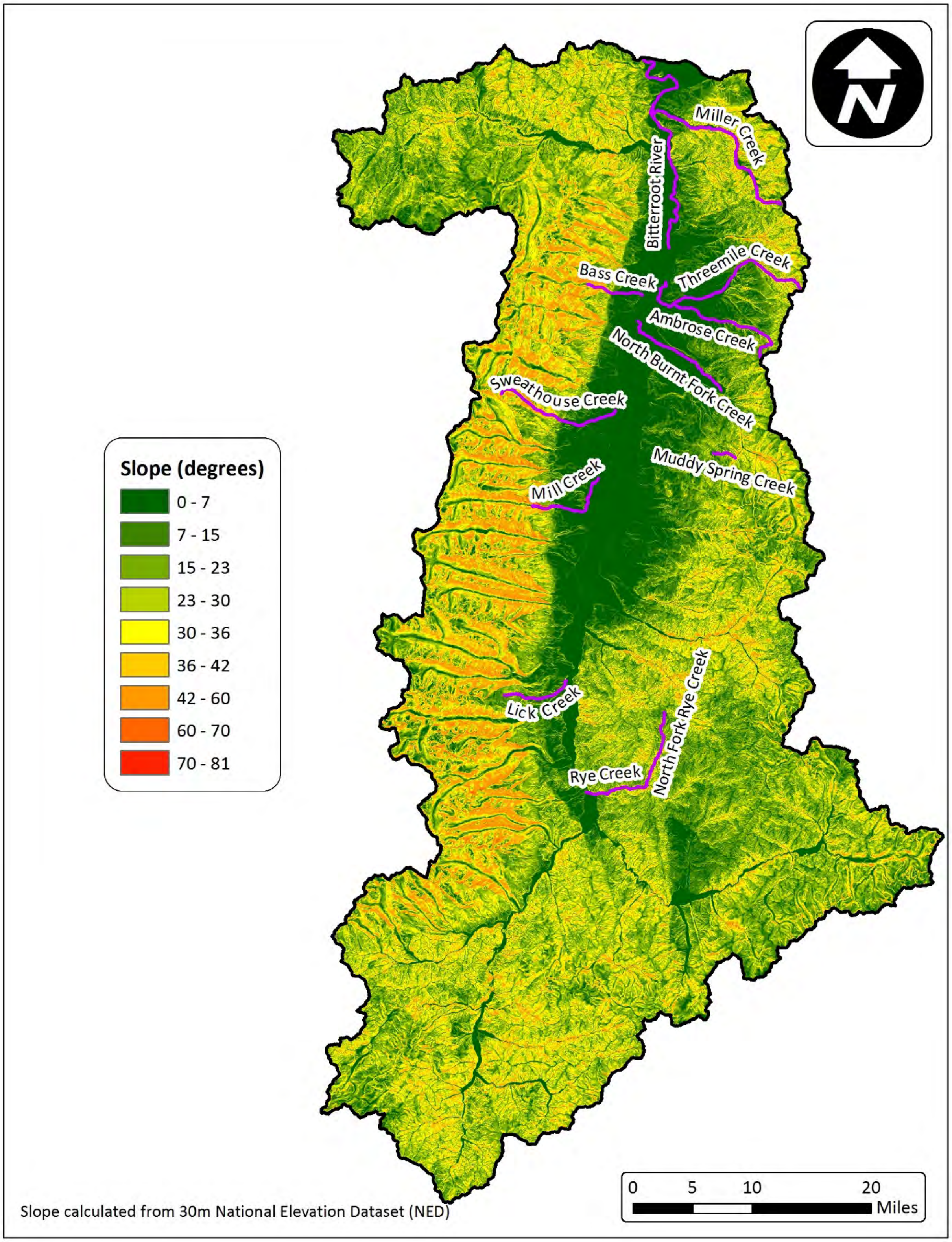


Figure A-4. Slope of the Bitterroot Watershed Project Area

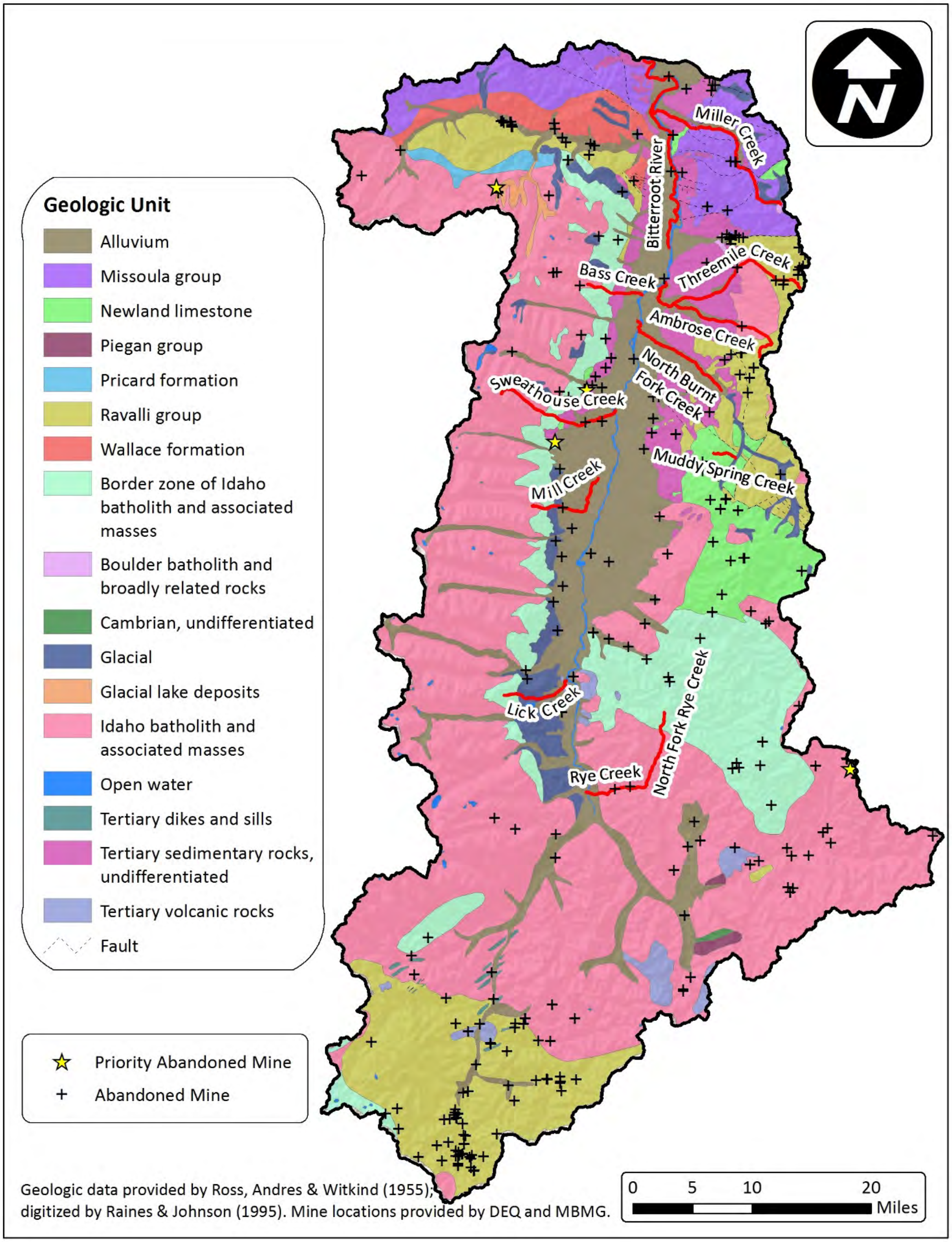


Figure A-5. Geologic units and abandoned mines of the Bitterroot Watershed Project Area

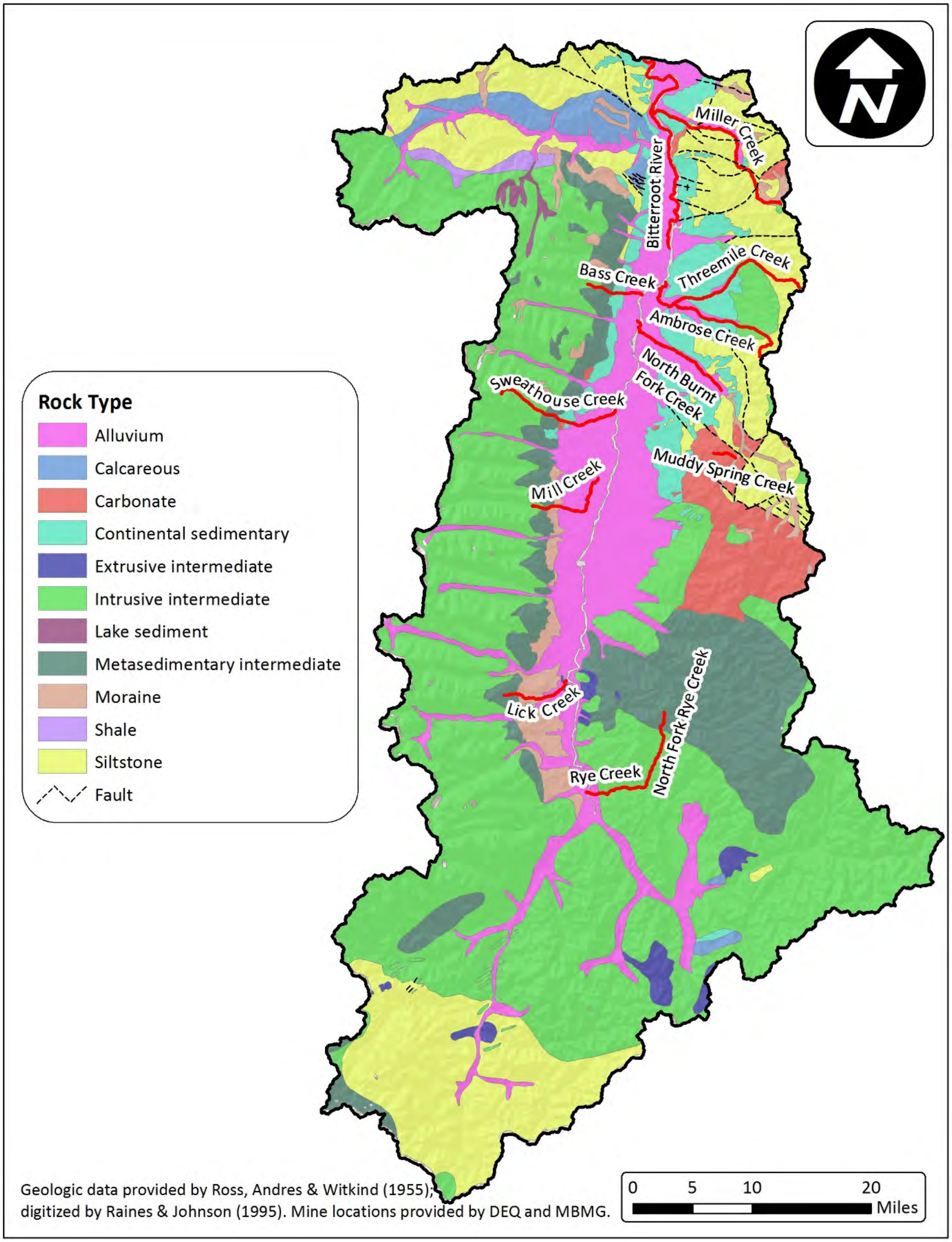


Figure A-6. Geologic rock types of the Bitterroot Watershed Project Area

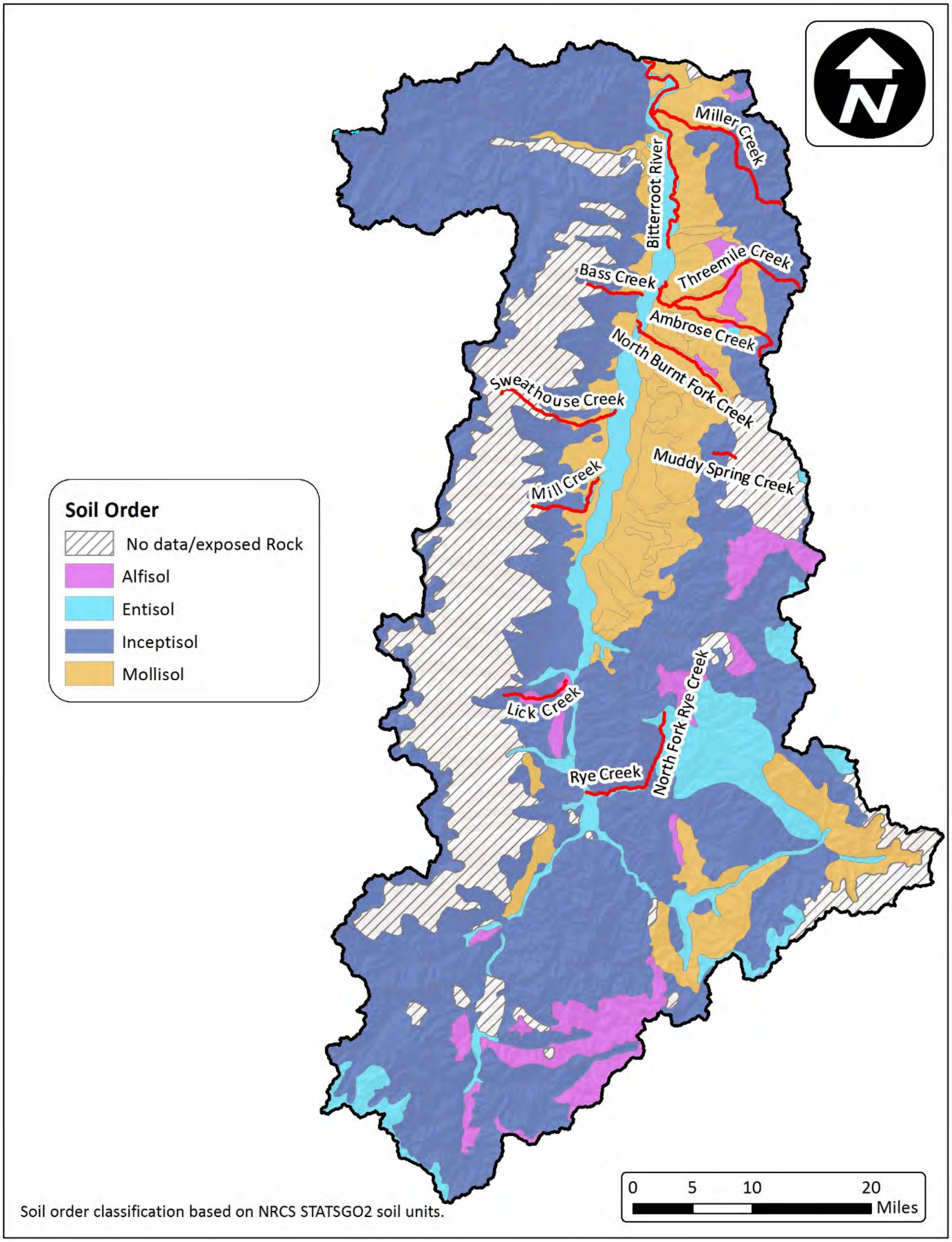


Figure A-7. Soil orders of the Bitterroot Watershed Project Area

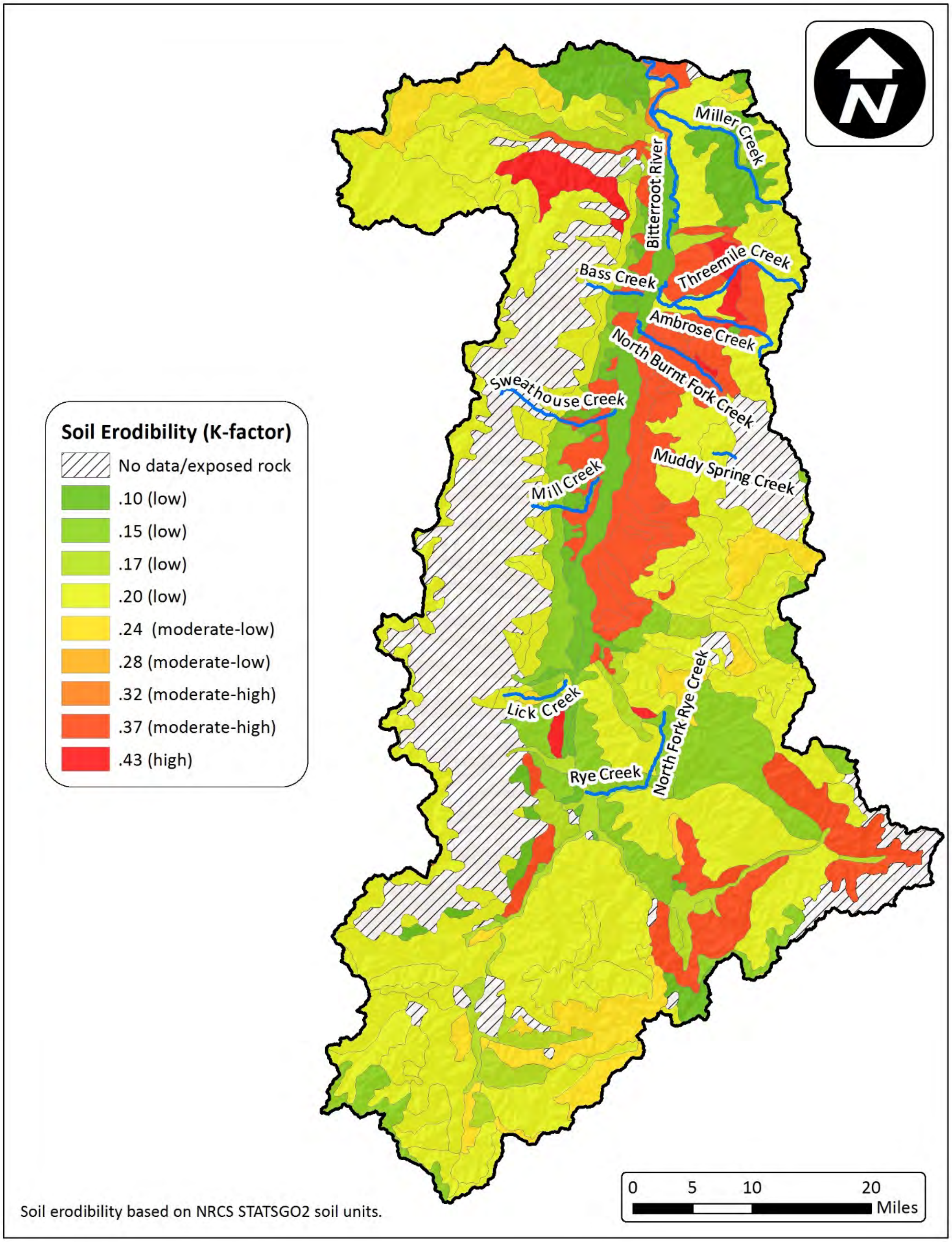


Figure A-8. Soil erodibility values of the Bitterroot Watershed Project Area

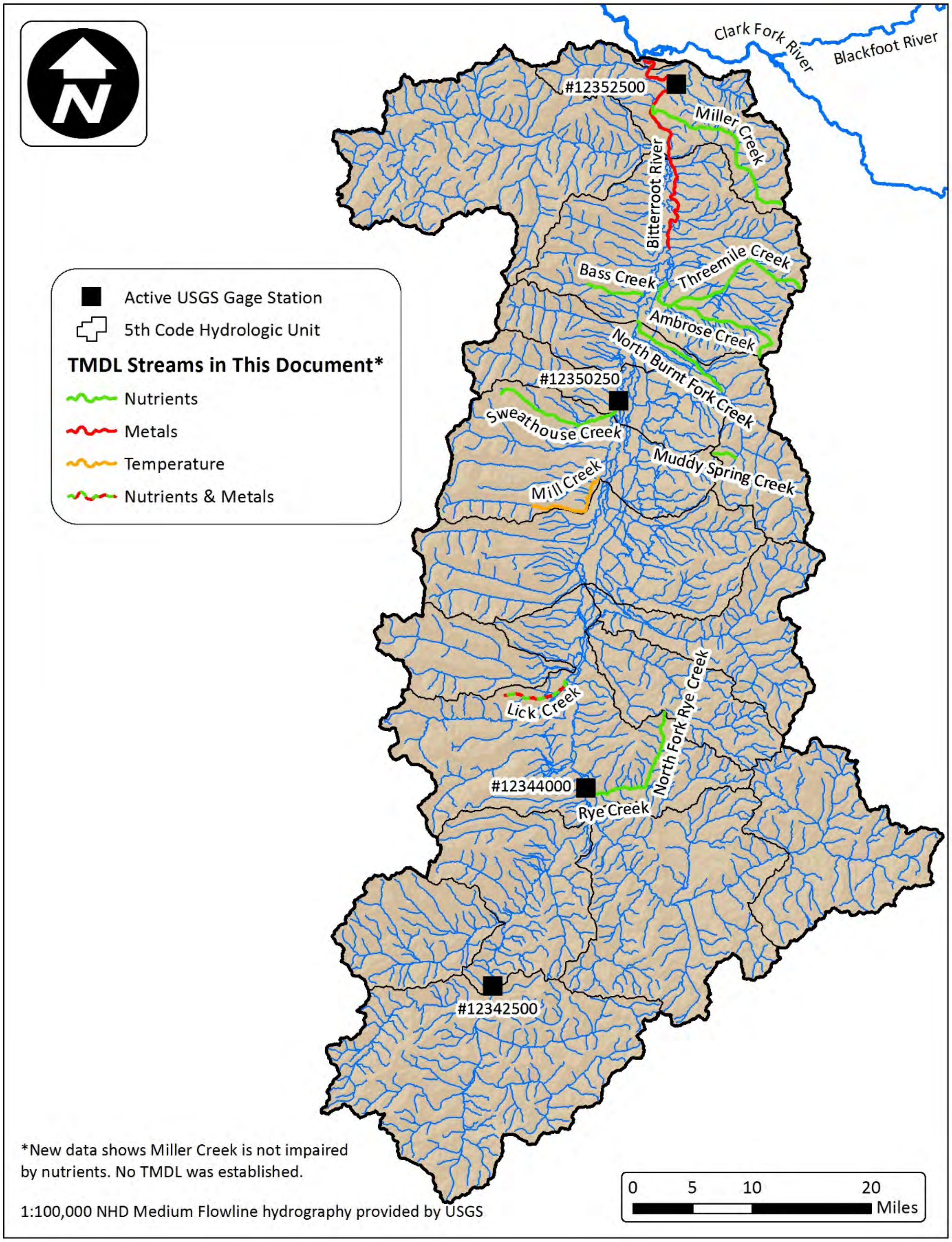


Figure A-9. Surface water hydrography of the Bitterroot Watershed Project Area

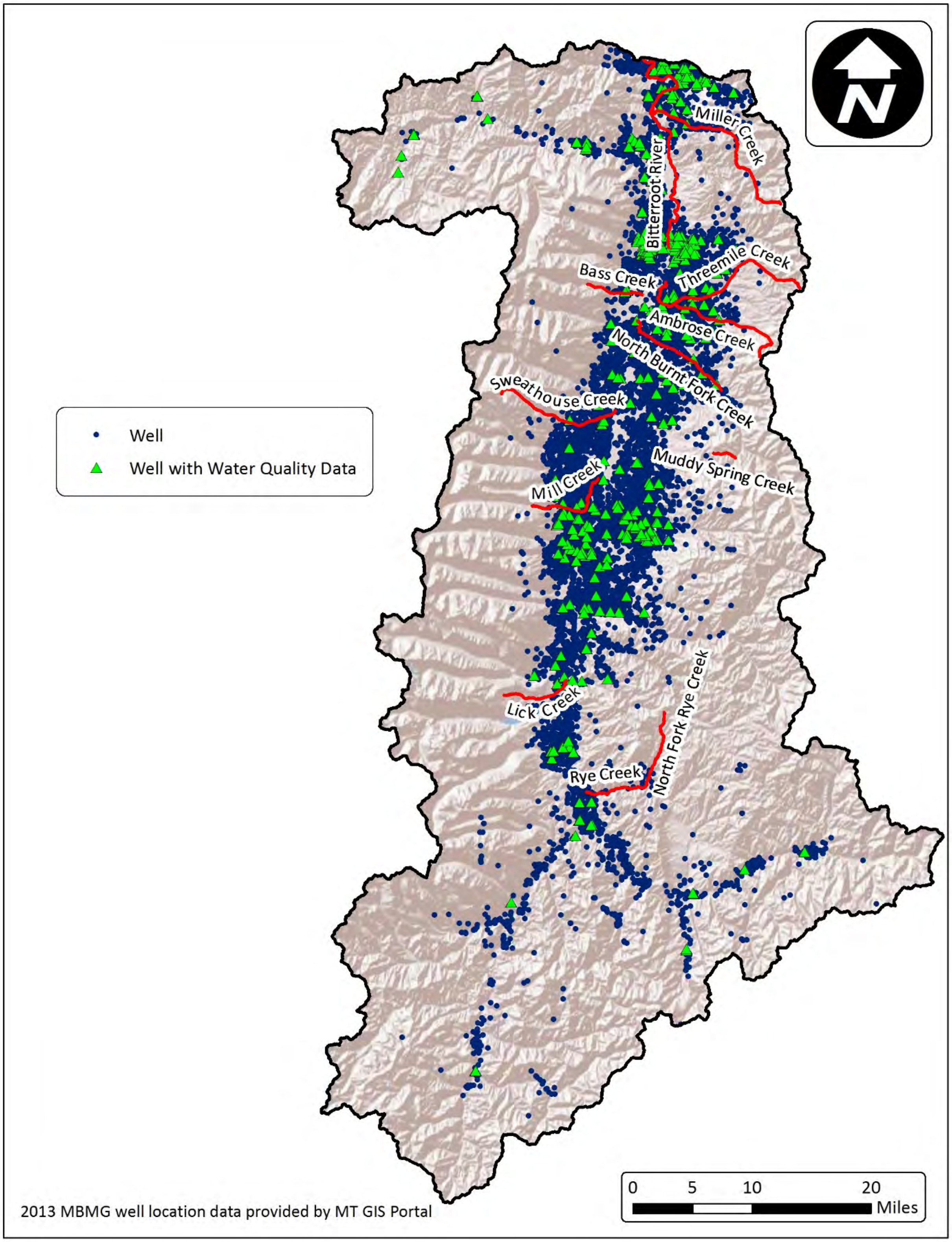


Figure A-10. Groundwater wells in the Bitterroot Watershed Project Area

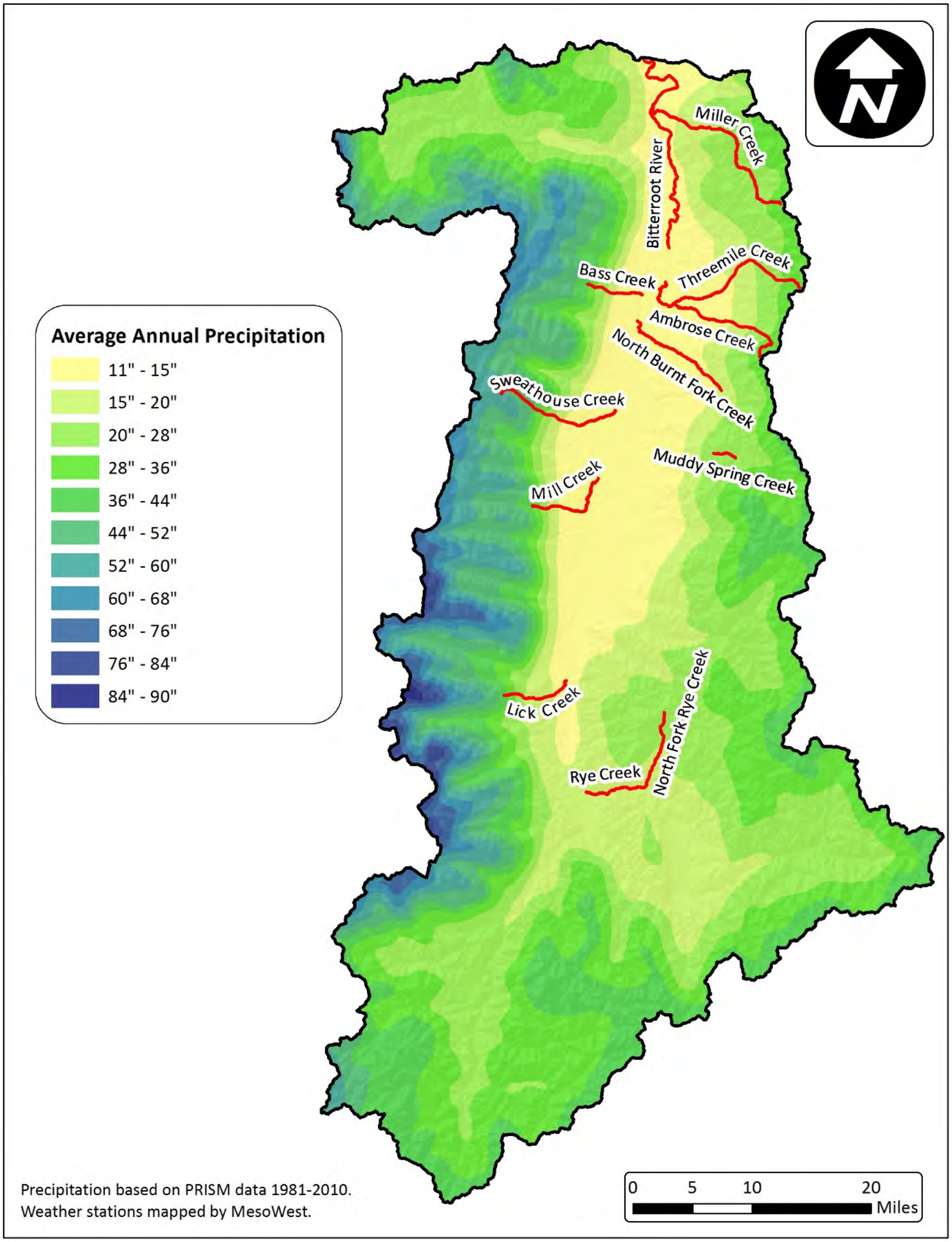


Figure A-11. Precipitation averages in the Bitterroot Watershed Project Area

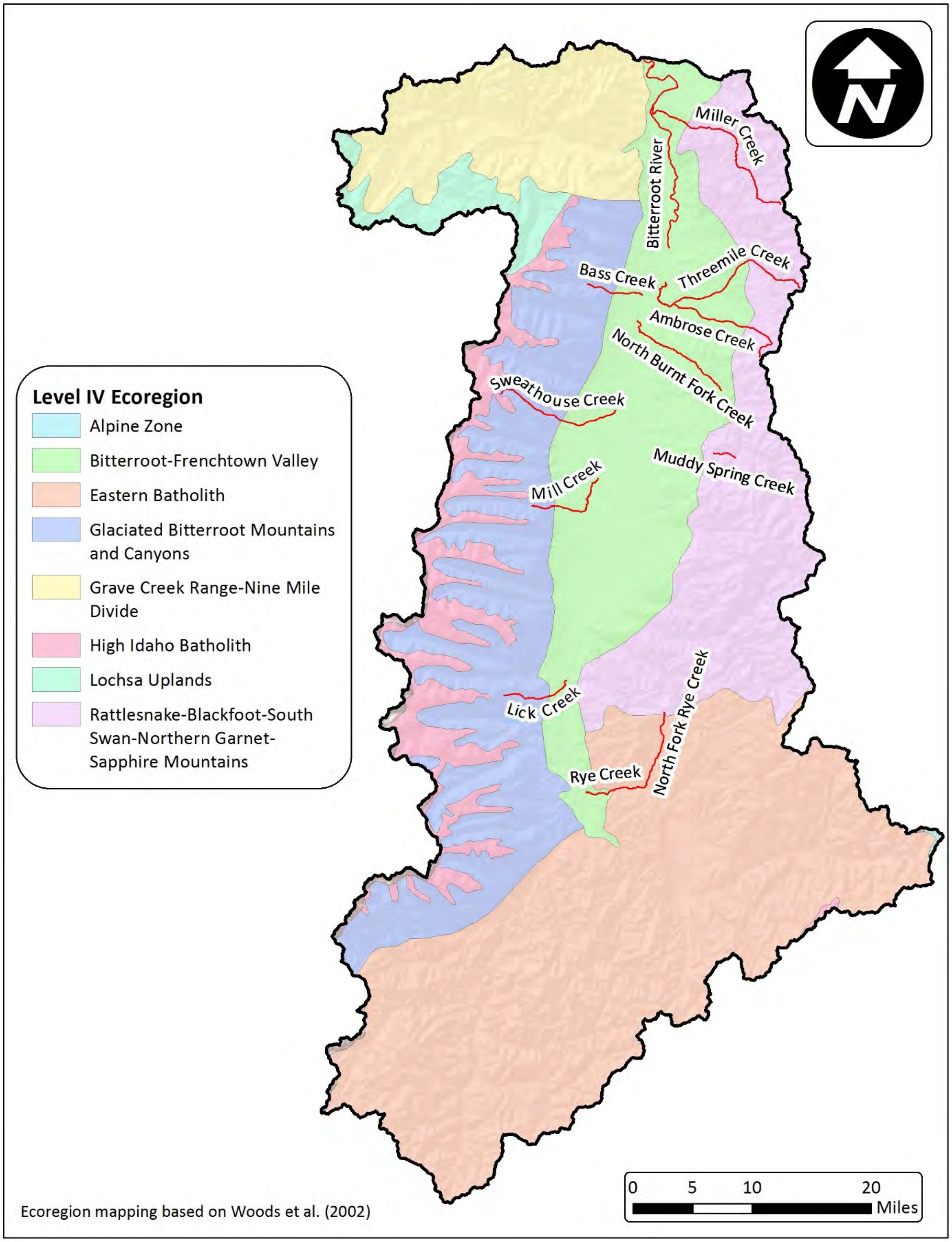


Figure A-12. Ecoregions of the Bitterroot Watershed Project Area

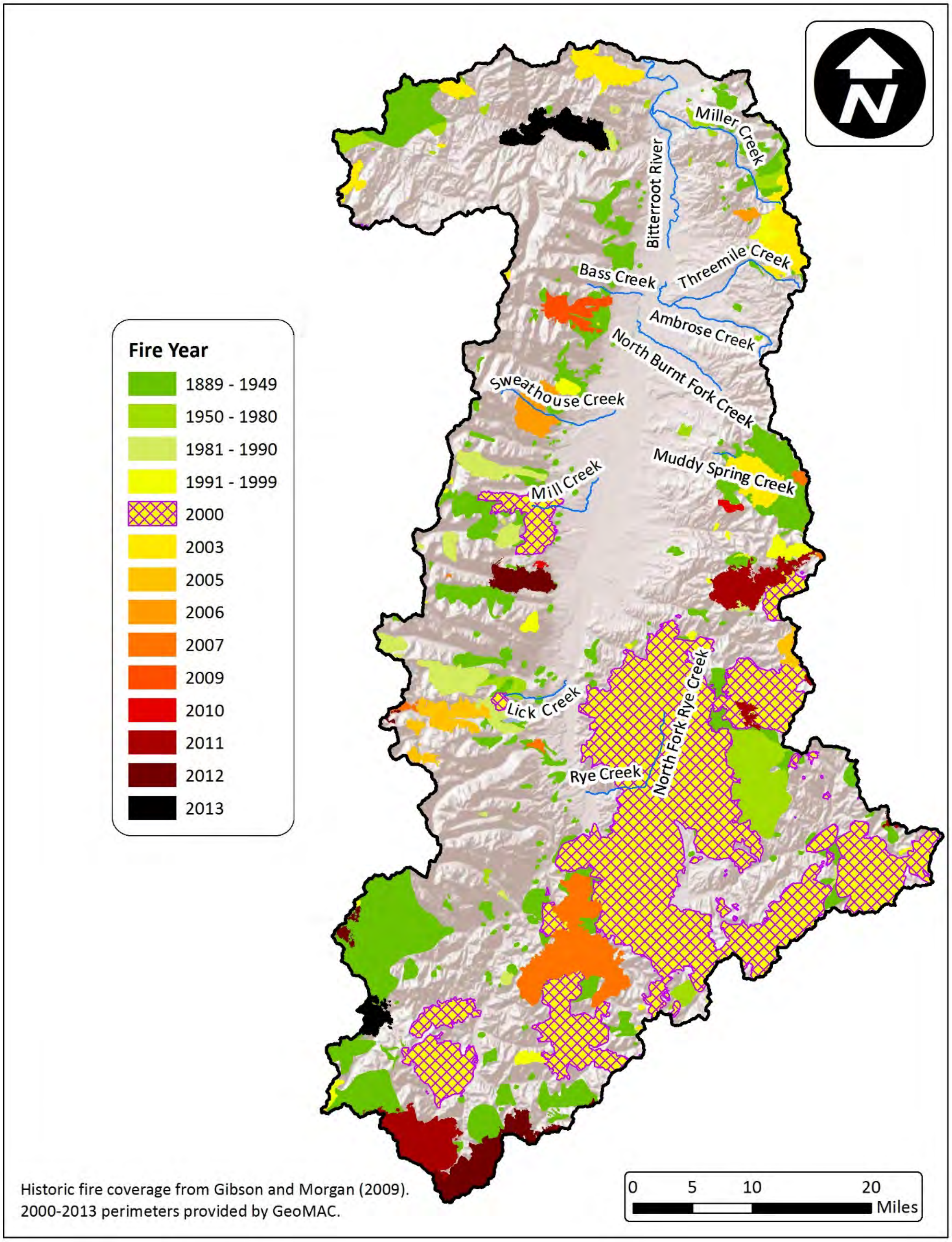


Figure A-13. Fire history of the Bitterroot Watershed Project Area

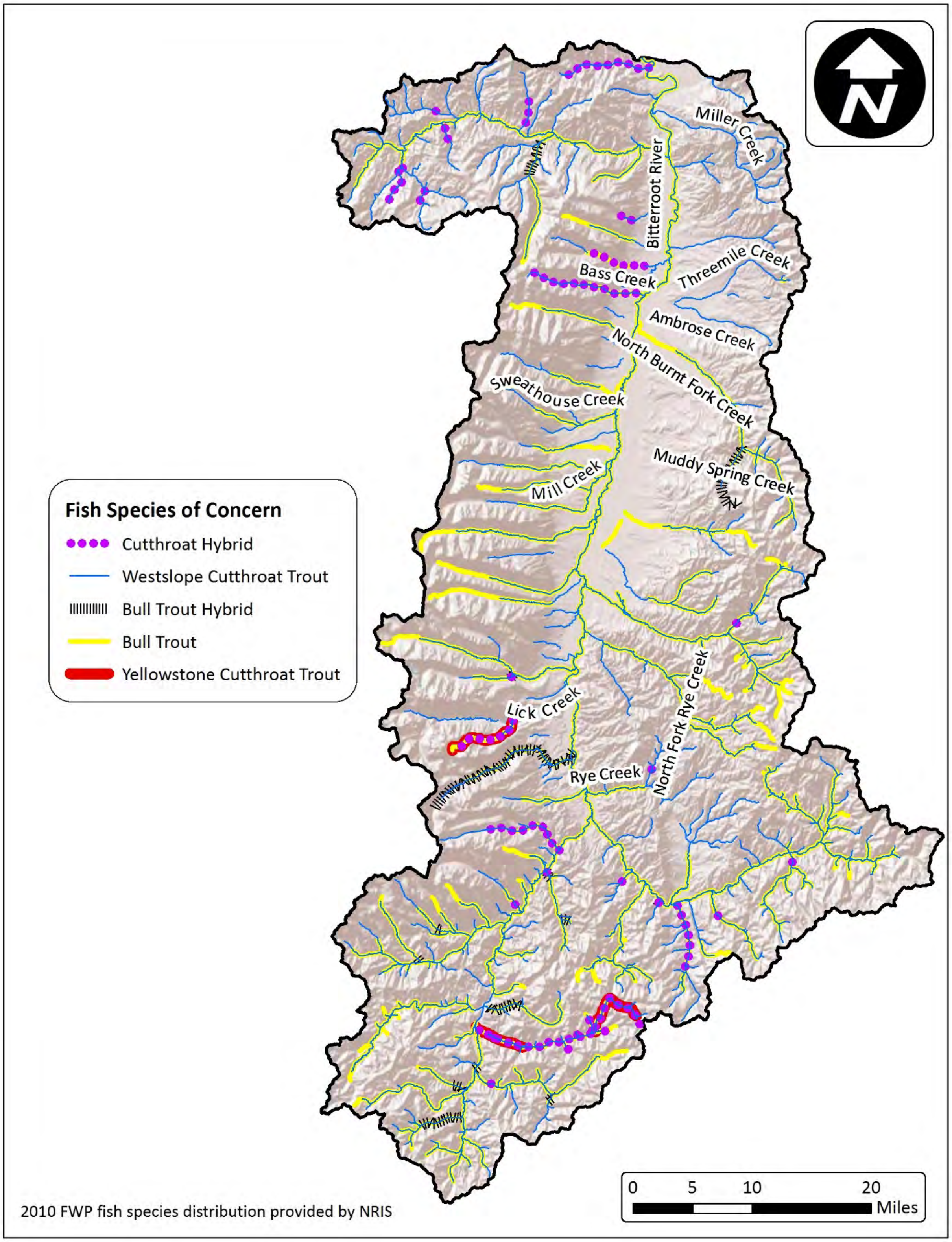


Figure A-14. Fish species of concern in the Bitterroot Watershed Project Area

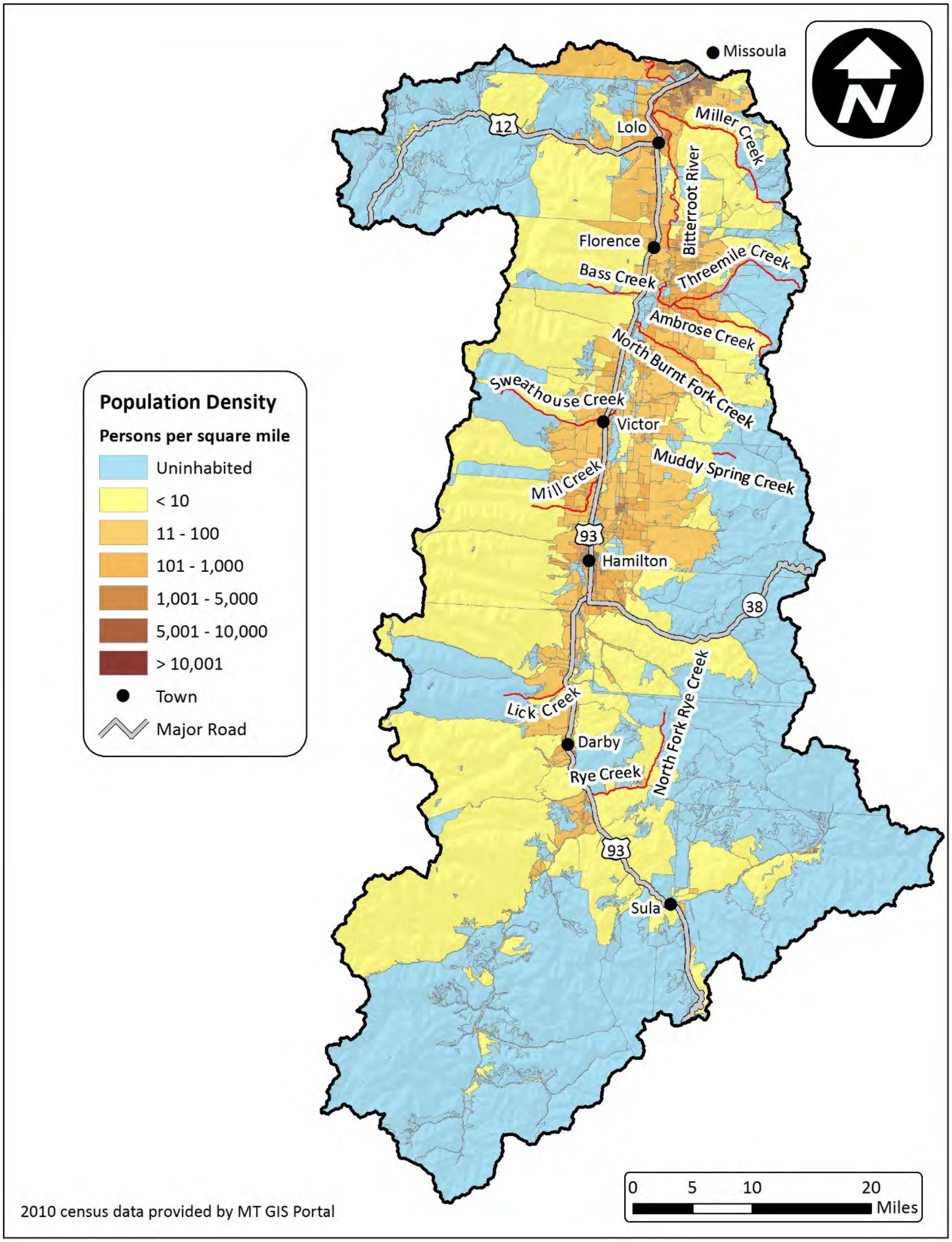


Figure A-15. Population density of the Bitterroot Watershed Project Area

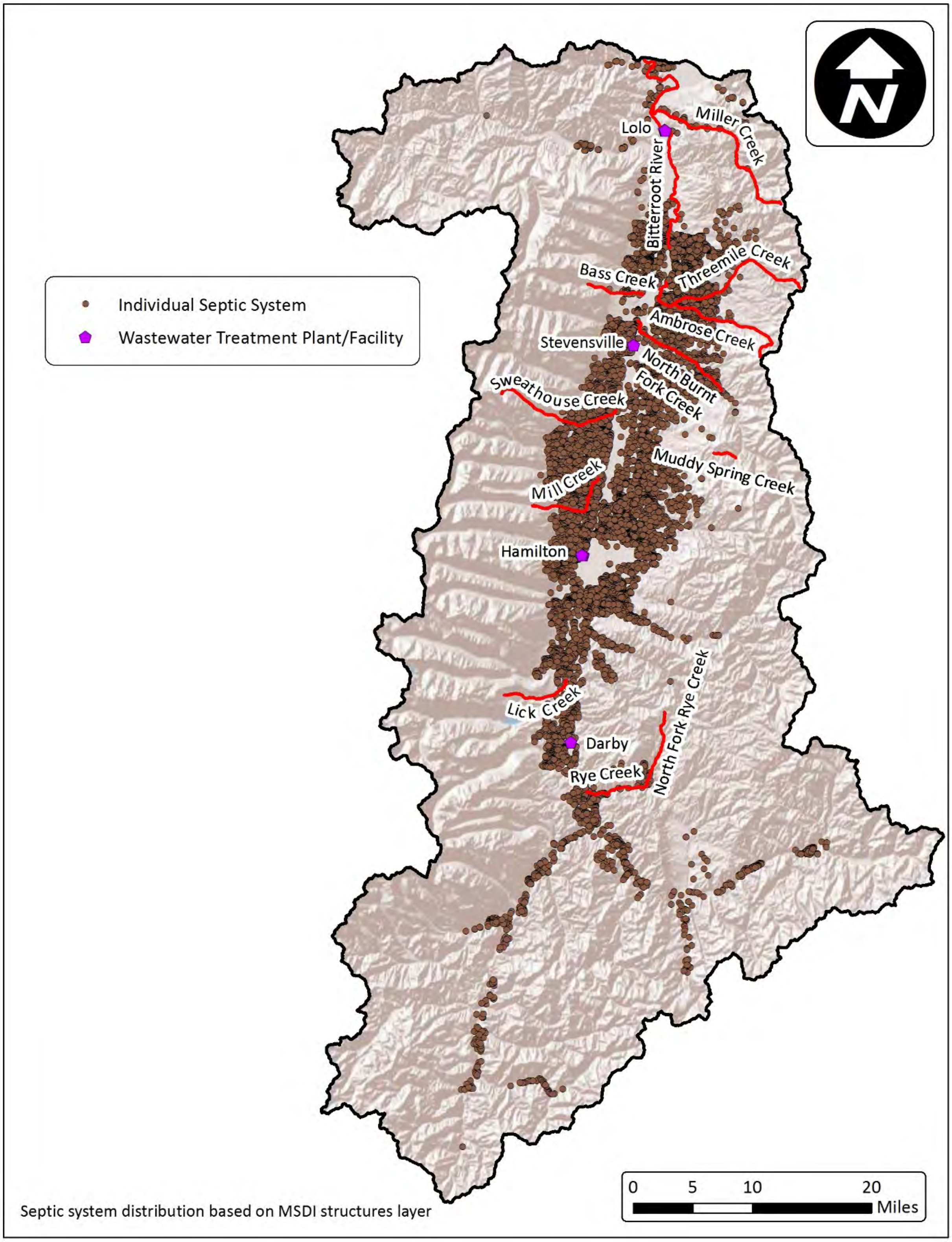


Figure A-16. Individual septic systems of the Bitterroot Watershed Project Area

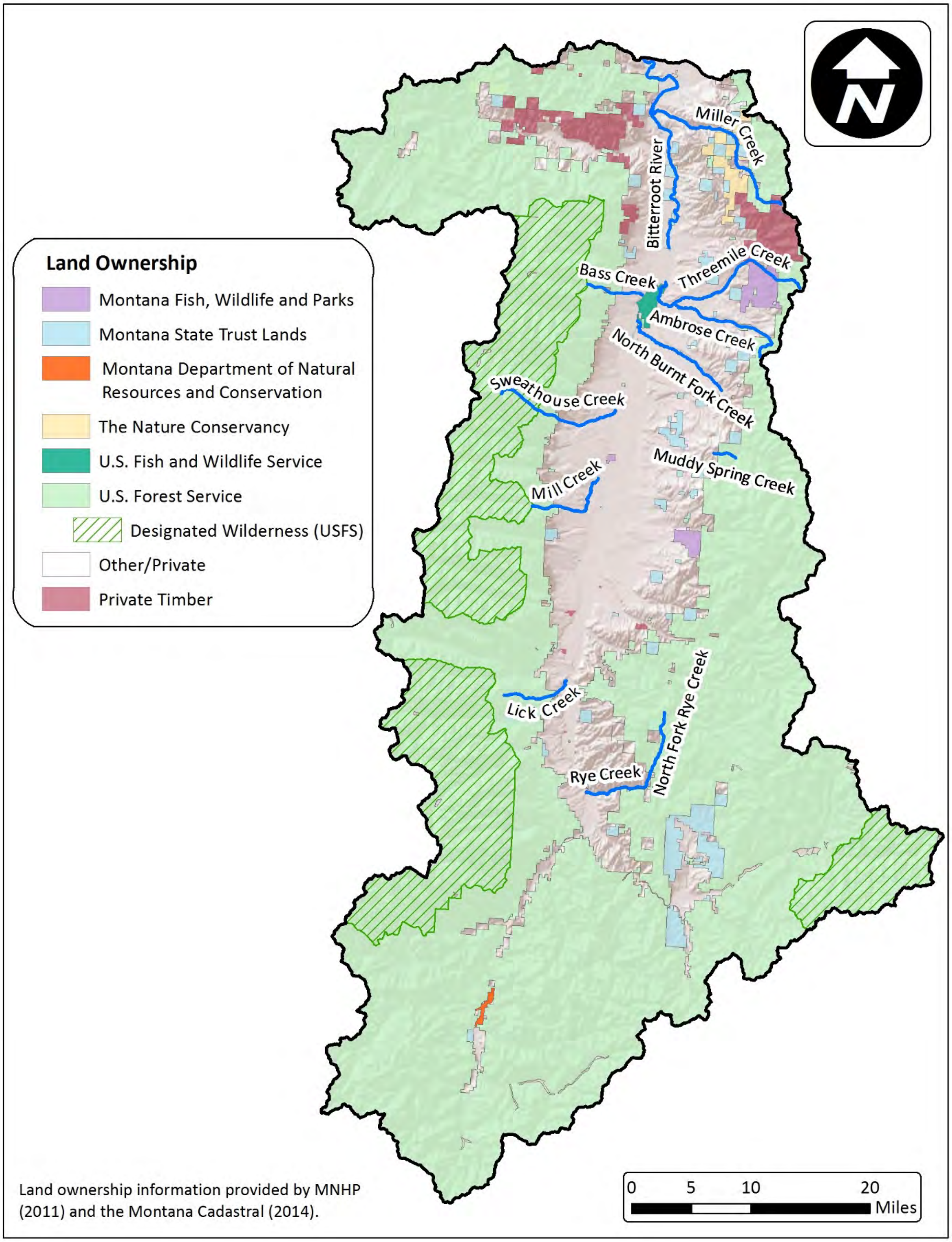


Figure A-17. Land ownership of the Bitterroot Watershed Project Area

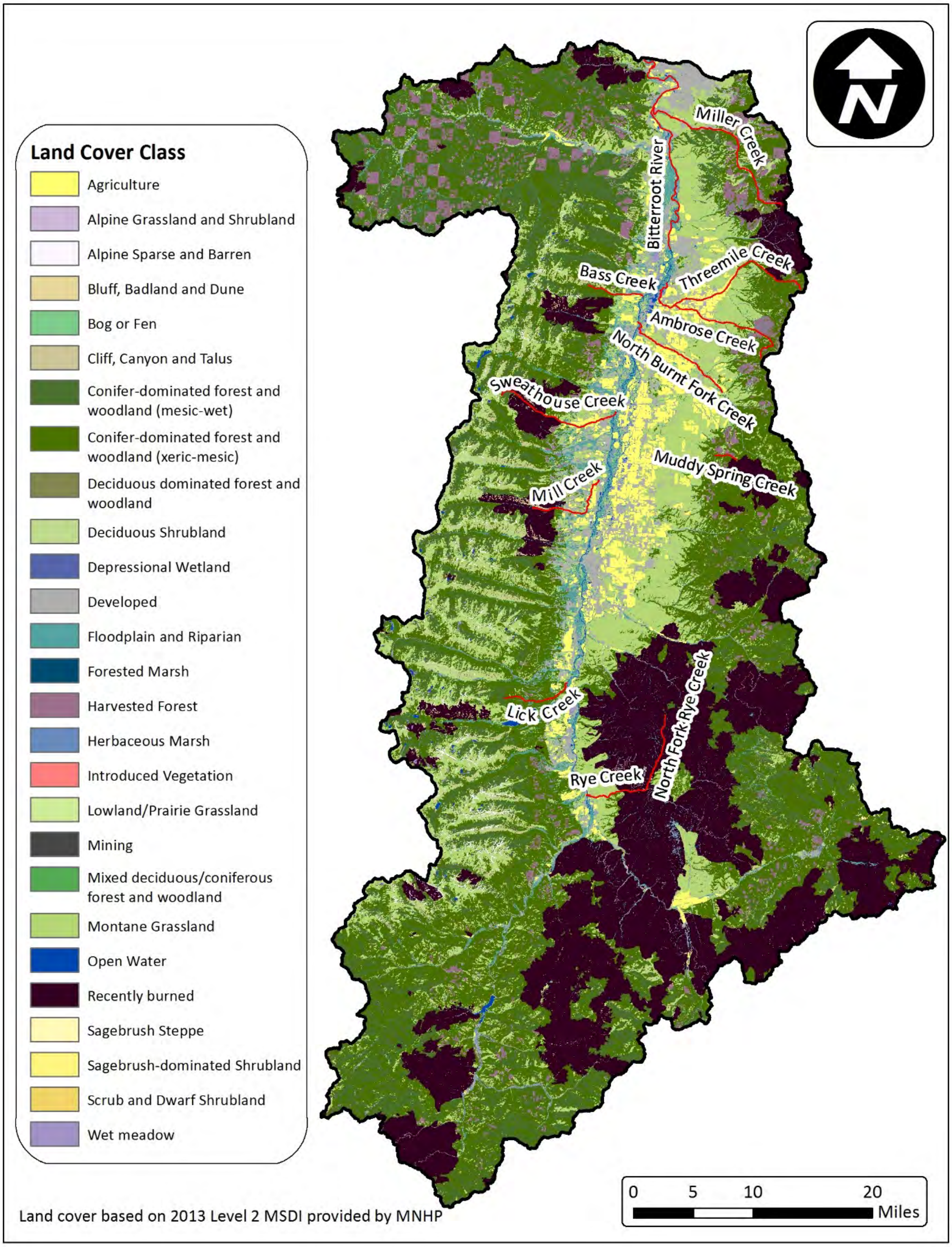


Figure A-18. Land cover of the Bitterroot Watershed Project Area

Appendix B - Regulatory Framework and Reference Condition Approach

This appendix presents details about applicable Montana Water Quality Standards (WQS) and the general and statistical methods used for development of reference conditions.

Table of Contents

List of Tables

List of Figures

ACRONYMS

Acronym	Definition
ARM	Administrative Rules of Montana
BER	Board of Environmental Review (Montana)
CFR	Code of Federal Regulations
CWA	Clean Water Act
DEQ	Department of Environmental Quality (Montana)
EPA	Environmental Protection Agency (US)
HHC	Human Health Criteria
MCA	Montana Codes Annotated
MCL	Maximum Contaminant Level
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TPA	TMDL Planning Area
TSS	Total Suspended Solids
UAA	Use Attainability Analysis
WQA	Water Quality Act
WQS	Water Quality Standards

B1.0 TMDL Development Requirements

Section 303(d) of the federal Clean Water Act (CWA) and the Montana Water Quality Act (WQA) (Section 75-5-703) requires development of TMDLs for impaired waterbodies that do not meet Montana WQS. Although waterbodies can become impaired from pollution (e.g. low flow alterations and habitat degradation) and pollutants (e.g. nutrients, sediment, metals, pathogens, and temperature), the CWA and Montana state law (75-5-703) require TMDL development only for impaired waters with pollutant causes. Section 303(d) also requires states to submit a list of impaired waterbodies to the U.S. Environmental Protection Agency (EPA) every two years. Prior to 2004, EPA and DEQ referred to this list simply as the 303(d) list.

Since 2004, EPA has requested that states combine the 303(d) list with the 305(b) report containing an assessment of Montana's water quality and its water quality programs. EPA refers to this new combined 303(d)/305(b) report as the Integrated Water Quality Report. The 303(d) list also includes identification of the probable cause(s) of the water quality impairment (e.g. pollutants such as metals, nutrients, sediment, pathogens or temperature), and the suspected source(s) of the pollutants of concern (e.g. various land use activities). State law (MCA 75-5-702) identifies that a sufficient credible data methodology for determining the impairment status of each waterbody is used for consistency. The impairment status determination methodology is identified in DEQ's Water Quality Assessment Process and Methods found in Attachment 1 of Montana's Water Quality Integrated Report (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012).

Under Montana state law, an "impaired waterbody" is defined as a waterbody or stream segment for which sufficient credible data show that the waterbody or stream segment is failing to achieve compliance with applicable WQS (Montana Water Quality Act; Section 75-5-103(11)). A "threatened waterbody" is defined as a waterbody or stream segment for which sufficient credible data and calculated increases in loads show that the waterbody or stream segment is fully supporting its designated uses, but threatened for a particular designated use because of either (a) proposed sources that are not subject to pollution prevention or control actions required by a discharge permit, the nondegradation provisions, or reasonable land, soil, and water conservation practices or (b) documented adverse pollution trends (Montana WQA; Section 75-5-103(31)). State law and Section 303(d) of the CWA require states to develop all necessary TMDLs for impaired or threatened waterbodies. None of the waterbodies being addressed within the scope of this document are listed as threatened.

A TMDL is a pollutant budget for a waterbody identifying the maximum amount of the pollutant that a waterbody can assimilate without causing applicable WQS to be exceeded (violated). TMDLs are often expressed in terms of an amount, or load, of a particular pollutant (expressed in units of mass per time such as pounds per day). TMDLs must account for loads/impacts from point and nonpoint sources in addition to natural background sources and must incorporate a margin of safety and consider influences of seasonality on analysis and compliance with WQS. **Section 4.0** of the main document provides a description of the components of a TMDL.

To satisfy the federal CWA and Montana state law, TMDLs are developed for each waterbody-pollutant combination identified on Montana's 303(d) list of impaired or threatened waters, and are often presented within the context of a water quality restoration or protection plan. State law (Administrative

Rules of Montana 75-5-703(8)) also directs Montana DEQ to "…support a voluntary program of reasonable land, soil, and water conservation practices to achieve compliance with water quality standards for nonpoint source activities for waterbodies that are subject to a TMDL…" This is an important directive that is reflected in the overall TMDL development and implementation strategy within this plan. It is important to note that water quality protection measures are not considered voluntary where such measures are already a requirement under existing federal, state, or local regulations.

B2.0 Applicable Water Quality Standards

WQS include the uses designated for a waterbody, the legally enforceable standards that ensure that the uses are supported, and a nondegradation policy that protects the high quality of a waterbody. The ultimate goal of this TMDL document, once implemented, is to ensure that all designated beneficial uses are fully supported and all water quality standards are met. Water quality standards form the basis for the targets described in **Sections 5.0**, **6.0**, and **7.0**. Pollutants addressed in this framework water quality improvement plan include nutrients, metals, and temperature. This section provides a summary of the applicable water quality standards for these pollutants.

B2.1 Classification and Beneficial Uses

Classification is the assignment (designation) of a single or group of uses to a waterbody based on the potential of the waterbody to support those uses. Designated uses or beneficial uses are simple narrative descriptions of water quality expectations or water quality goals. There are a variety of "uses" of state waters including growth and propagation of fish and associated aquatic life; drinking water; agriculture; industrial supply; and recreation and wildlife. The Montana WQA directs the Board of Environmental Review (BER) (i.e., the state) to establish a classification system for all waters of the state that includes their present (when the Act was originally written) and future most beneficial uses (ARM 17.30.607-616) and to adopt standards to protect those uses (ARM 17.30.620-670).

Montana, unlike many other states, uses a watershed-based classification system, with some specific exceptions. As a result, *all* waters of the state are classified and have designated uses and supporting standards. All classifications have multiple uses and in only one case (A-Closed) is a specific use (drinking water) given preference over the other designated uses. Some waters may not actually be used for a specific designated use, for example as a public drinking water supply; however, the quality of that waterbody must be maintained suitable for that designated use. When natural conditions limit or preclude a designated use, permitted point source discharges or nonpoint source activities or pollutant discharges must not make the natural conditions worse.

Modification of classifications or standards that would lower a water's classification or a standard (i.e., B-1 to a B-3), or removal of a designated use because of natural conditions, can only occur if the water was originally misclassified. All such modifications must be approved by the BER, and are undertaken via a Use Attainability Analysis (UAA) that must meet EPA requirements (40 CFR 131.10(g), (h) and (j)). The UAA and findings presented to the BER during rulemaking must prove that the modification is correct and all existing uses are supported. An existing use cannot be removed or made less stringent.

Descriptions of Montana's surface water classifications and designated beneficial uses are presented in **Table B2-1**. In 2003, Montana added four classes: D, E, F, and G. These classes include ephemeral streams (E-1 and E-2), ditches (D-1 and D-2), seasonal or semi-permanent lakes and ponds (E-3, E-4, E-5) and waters with low or sporadic flow (F-1). All waterbodies within the Bitterroot Watershed Project Area are classified as B-1 (see **Section 3.1** and **Table 3-1** in the main document for individual stream classifications).

Table B2-1. Montana Surface Water Classifications and Designated Beneficial Uses

Classification	Designated Uses
A-CLOSED:	Waters classified A-Closed are to be maintained suitable for drinking, culinary and food processing purposes after simple disinfection.
A-1:	Waters classified A-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment for removal of naturally present impurities.
B-1:	Waters classified B-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
B-2:	Waters classified B-2 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
B-3:	Waters classified B-3 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-1:	Waters classified C-1 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-2:	Waters classified C-2 are to be maintained suitable for bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-3:	Waters classified C-3 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers. The quality of these waters is naturally marginal for drinking, culinary and food processing purposes, agriculture and industrial water supply.
I:	The goal of the State of Montana is to have these waters fully support the following uses: drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
D-1:	Waters classified D-1 are to be maintained suitable for agricultural purposes and secondary contact recreation.
D-2:	Waters classified D-2 are to be maintained suitable for agricultural purposes and secondary contact recreation. Because of conditions resulting from low flow regulations, maintenance of the ditch, or geomorphologic and riparian habitat conditions, quality is marginally suitable for aquatic life.
E-1:	Waters classified E-1 are to be maintained suitable for agricultural purposes, secondary contact recreation, and wildlife.
E-2:	Waters classified E-2 are to be maintained suitable for agricultural purposes, secondary contact recreation, and wildlife. Because of habitat, low flow, hydro-geomorphic, and other physical conditions, waters are marginally suitable for aquatic life.
E-3:	Waters classified E-3 are to be maintained suitable for agricultural purposes, secondary contact recreation, and wildlife.

Table B2-1. Montana Surface Water Classifications and Designated Beneficial Uses

Classification	Designated Uses
E-4:	Waters classified E-4 are to be maintained suitable for aquatic life, agricultural purposes, secondary contact recreation, and wildlife.
E-5:	Waters classified E-5 are to be maintained suitable for agricultural purposes, secondary contact recreation, saline-tolerant aquatic life, and wildlife.
F-1:	Waters classified F-1 are to be maintained suitable for secondary contact recreation, wildlife, and aquatic life, not including fish.
G-1:	Waters classified G-1 are to be maintained suitable for watering wildlife and livestock; aquatic life, not including fish; secondary contact recreation; marginally suitable for irrigation after treatment or with mitigation measures.

B2.2 STANDARDS

In addition to the use classifications described above, Montana's WQS include numeric and narrative criteria as well as a nondegradation policy.

Numeric Standards

Numeric surface water quality standards have been developed for many parameters to protect human health and aquatic life. These standards are in the Department Circular DEQ-7 (Montana Department of Environmental Quality, 2012) . The numeric human health standards have been developed for parameters determined to be toxic, carcinogenic, or harmful and have been established at levels to be protective of long-term (i.e., lifelong) exposures as well as through direct contact such as swimming.

The numeric aquatic life standards include chronic and acute values that are based on extensive laboratory studies including a wide variety of potentially affected species, a variety of life stages and durations of exposure. Chronic aquatic life standards are protective of long-term exposure to a parameter. The protection afforded by the chronic standards includes detrimental effects to reproduction, early life stage survival and growth rates. In most cases the chronic standard is more stringent than the corresponding acute standard. Acute aquatic life standards are protective of short-term exposures to a parameter and are not to be exceeded.

High quality waters are afforded an additional level of protection by the nondegradation rules (ARM 17.30.701 et. seq.,) and in statute (75-5-303 MCA). Changes in water quality must be "non-significant", or an authorization to degrade must be granted by the DEQ. However, under no circumstance may standards be exceeded. It is important to note that waters that meet or are of better quality than a standard are high quality for that parameter, and nondegradation policies apply to new or increased discharges to that the waterbody.

Narrative Standards

Narrative standards have been developed for substances or conditions for which sufficient information does not exist to develop specific numeric standards. The term "Narrative Standards" commonly refers to the General Prohibitions in ARM 17.30.637 and other descriptive portions of the surface WQS. The General Prohibitions are also called the "free from" standards; that is, the surface waters of the state must be free from substances attributable to discharges, including thermal pollution, that impair the beneficial uses of a waterbody. Uses may be impaired by toxic or harmful conditions (from one or a combination of parameters) or conditions that produce undesirable aquatic life. Undesirable aquatic life includes bacteria, fungi, and algae.

The standards applicable to the list of pollutants addressed in the Bitterroot Watershed Project Area TMDLs are summarized below. In addition to the standards below, the beneficial-use support standard for B-1 streams, as defined above, can apply to other conditions, often linked to pollution, limiting aquatic life. These other conditions can include effects from dewatering/flow alterations and effects from habitat modifications.

B.2.2.1 Nutrient Standards

The narrative standards applicable to nutrients in Montana are contained in the General Prohibitions of the surface water quality standards (ARM 17.30.637 et. Seq.,). The prohibition against the creation of "*conditions which produce undesirable aquatic life*" is generally the most relevant to nutrients. Undesirable aquatic life includes bacteria, fungi, and algae. Montana has recently developed nutrient criteria for nitrate+nitrite nitrogen (NO_2+NO_3), total nitrogen (TN), total phosphorus (TP), and chlorophyll-*a* based on the Level III ecoregion in which a stream is located (Suplee et al., 2012). For the Northern Rockies and Idaho Batholith Level III Ecoregions, water quality criteria for TN and TP are presented in **Table B2-2**. These criteria are growing season, or summer, values applied from July 1st through September 30th. Additionally, numeric human health standards exist for nitrogen (**Table B2-3**), but the narrative standard is most applicable to nutrients as the concentration in most waterbodies in Montana is well below the human health standard and the nutrients contribute to undesirable aquatic life at much lower concentrations than the human health standard.

Table B2-2. Numeric Nutrient Criteria for the Bitterroot Project Area, by Ecoregion

Parameter	Target Values	
	Middle Rockies (Level III)	Idaho Batholith (Level III)
Total Nitrogen (TN)	≤ 0.300 mg/L	≤ 0.275 mg/L
Total Phosphorous (TP)	≤ 0.030 mg/L	≤ 0.025 mg/L

Table B2-3. Human Health Standards for Nitrogen for the State of Montana.

Parameter	Human Health Standard (µL)[1]
Nitrate as Nitrogen (NO_3-N)	10,000
Nitrite as Nitrogen (NO_2-N)	1,000
Nitrate plus Nitrite as N	10,000

[1]Maximum Allowable Concentration.

B.2.2.2 Metals Standards

Water quality standards that are applicable to metals impairments include both numeric water quality criteria given in DEQ-7 (**Table B2-5**) and general prohibitions (narrative criteria) given in **Table B2-6.** As water quality criteria for many metals is dependent upon water hardness, **Table B2-5** presents acute and chronic metals numeric water quality criteria at water harnesses of 25, 100 and 400 mg/L for metals of concern in the Bitterroot Watershed Project Area. Also presented in **Table B2-5** is the Human Health Criteria (HHC): note that for mercury and arsenic, the HHC is lower than applicable chronic criteria.

For iron, the human health standard (i.e., 300ug/L) is a secondary maximum contaminant level that is based on <u>aesthetic</u> water properties such as taste, odor, and the tendency of these metals to cause staining. Iron is not classified as a toxin or a carcinogen. Therefore, for the purposes of this TMDL document, the secondary MCL guidance values for iron is not applied or considered in the evaluation of water quality data. The chronic aquatic life standard of 1,000 µg/L for iron is used as the metals target for iron.

It should be noted that recent studies have indicated in some streams metals concentrations may vary throughout the day because of diel pH and alkalinity changes. In some cases the variation can cross the standard threshold (both ways) for a metal. Montana water quality standards are not time of day dependent.

Table B2-4. Metals Numeric Water Quality Criteria for the Bitterroot Watershed Project Area.

Metal of concern	Aquatic life criteria (ug/L) at 25 mg/L hardness		Aquatic life criteria (ug/L) at 100 mg/L hardness		Aquatic life criteria (ug/L) at 400 mg/L hardness		HHS (ug/L)
	Acute	Chronic	Acute	Chronic	Acute	Chronic	
Aluminum, dissolved	750	87	750	87	750	87	---
Antimony, TR	---	---	---	---	---	---	5.6
Arsenic, TR	340	150	340	150	340	150	10
Cadmium, TR	0.52	0.1	2.1	0.27	8.7	0.76	5
Copper, TR	3.79	2.85	14	9.33	51.7	30.5	1,300
Cyanide, Total	22	5.2	22	5.2	22	5.2	140
Iron, TR	---	1,000	---	1,000	---	1,000	300*
Lead, TR	13.98	0.545	81.6	3.18	476.8	18.58	15
Mercury, Total	1.7	0.91	1.7	0.91	1.7	0.91	0.05
Zinc, TR	37	37	119.8	119.8	387.8	387.8	2,000

*Human Health Standards (HHS)for iron is a secondary maximum contaminant level based on aesthetic properties
TR = total recoverable

In addition to numeric criteria given in **Table B2-4**, narrative criteria also provides protection of beneficial uses. Toxic levels of metals in stream sediment are prohibited via ARM 17.30.637(1)(d). Metals concentrations in stream sediment are addressed via the suite of narrative criteria presented in **Table B2-5**. The relevant narrative criteria do not allow for 'concentrations or combinations of materials that are toxic or harmful to human, animal, plant, or aquatic life.' This is interpreted to mean that water quality goals should strive toward a condition in which any increases in metals concentration in sediment above naturally occurring levels are not harmful, detrimental or injurious to beneficial uses (see definitions in **Table B2-5**). Evaluation of numeric and narrative criteria for specific metals impairments by stream segment is given in **Section 6.4.3**.

Table B2-5. Applicable Rules for Metals Concentrations in Sediment

Rule(s)	Criteria
17.30.623 (1) 17.30.624 (1)	Waters classified B-1 (B-2) are to be maintained suitable for drinking, culinary, and food processing purposes, after conventional treatment; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
17.30.623(2) 17.30.624(2)	No person may violate the following specific water quality standards for waters classified B-1 (B-2).
17.30.623 (2)(f) 17.30.624 (2)(f)	(f) No increases are allowed above naturally occurring concentrations of sediment or suspended sediment (except as permitted in 75-5-318, MCA), settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation,

Table B2-5. Applicable Rules for Metals Concentrations in Sediment

Rule(s)	Criteria
17.30.623 (2)(h) 17.30.624 (2)(h)	(h) Concentrations of carcinogenic, bioconcentrating, toxic, radioactive, nutrient, or harmful parameters may not exceed the applicable standards set forth in department Circular DEQ-7.
17.30.637	General Prohibitions
17.30.637(1)	State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will.
17.30.637(1)(d)	Create concentrations or combinations of materials that are toxic or harmful to human, animal, plant, or aquatic life.

B.2.2.3.1 pH Standards

Waterbodies impaired by metals are also sometimes impaired by pH as a result of acid mine drainage. For human health, changes in pH are addressed by the general narrative criteria in ARM 17.30.601 et seq. and ARM 17.30.1001 et seq. For aquatic life, which can be sensitive to small pH changes, criteria are specified for each waterbody use classification. For B-1 waters, ARM 17.30.623(2)(c) states “Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 8.5 must be less than 0.5 pH unit. Natural pH outside this range must be maintained without change. Natural pH above 7.0 must be maintained above 7.0.”

B.2.2.4 Temperature Standards

Montana’s temperature standards were originally developed to address situations associated with point source discharges, making them somewhat awkward to apply when dealing with primarily nonpoint source issues. In practical terms, the temperature standards address a maximum allowable increase above “naturally occurring” temperatures to protect the existing temperature regime for fish and aquatic life. Additionally, Montana’s temperature standards address the maximum allowable decrease or rate at which cooling temperature changes (below naturally occurring) can occur to avoid fish and aquatic life temperature shock.

For waters classified as B-1; from Rule 17.30.622(e) and 17.30.623(e):
A 1^{o} F maximum increase above naturally occurring water temperature is allowed within the range 32^{o} F to 66^{o} F; within the naturally occurring range of 66^{o} F to 66.5^{o} F, no discharge is allowed which will cause the water temperature to exceed 67^{o} F; and where the naturally occurring water temperature is 66.5^{o} F or greater, the maximum allowable increase in water temperature is 0.5^{o} F. A 2^{o} F per-hour maximum decrease below naturally occurring water temperature is above 55^{o} F. A 2^{o} F maximum decrease below naturally occurring water temperature is allowed within the range of 55^{o} F to 32^{o} F.

B3.0 Reference Conditions

B3.1 Reference Conditions as Defined in DEQ’s Standard Operating Procedure for Water Quality Assessment (2006)

DEQ uses the reference condition to evaluate compliance with many of the narrative WQS. The term “reference condition” is defined as the condition of a waterbody capable of supporting its present and future beneficial uses when all reasonable land, soil, and water conservation practices have been applied. In other words, reference condition reflects a waterbodies greatest potential for water quality given historic land use activities.

DEQ applies the reference condition approach for making beneficial use-support determinations for certain pollutants (such as sediment) that have specific narrative standards. All classes of waters are subject to the provision that there can be no increase above naturally occurring concentrations of sediment and settleable solids, oils, or floating solids sufficient to create a nuisance or render the water harmful, detrimental, or injurious. These levels depend on site-specific factors, so the reference conditions approach is used.

Also, Montana WQS do not contain specific provisions addressing nutrients (nitrogen and phosphorous), or detrimental modifications of habitat or flow. However, these factors are known to adversely affect beneficial uses under certain conditions or combination of conditions. The reference conditions approach is used to determine if beneficial uses are supported when nutrients, flow, or habitat modifications are present.

Waterbodies used to determine reference condition are not necessarily pristine or perfectly suited to giving the best possible support to all possible beneficial uses. Reference condition also does not reflect an effort to turn the clock back to conditions that may have existed before human settlement, but is intended to accommodate natural variations in biological communities, water chemistry, etc. due to climate, bedrock, soils, hydrology, and other natural physiochemical differences. The intention is to differentiate between natural conditions and widespread or significant alterations of biology, chemistry, or hydrogeomorphology due to human activity. Therefore, reference conditions should reflect minimum impacts from human activities. It attempts to identify the potential condition that could be attained (given historical land use) by the application of reasonable land, soil, and water conservation practices. DEQ realizes that pre-settlement water quality conditions usually are not attainable.

Comparison of conditions in a waterbody to reference waterbody conditions must be made during similar season and/or hydrologic conditions for both waters. For example, the Total Suspended Solids (TSS) of a stream at base flow during the summer should not be compared to the TSS of reference condition that would occur during a runoff event in the spring. In addition, a comparison should not be made to the lowest or highest TSS values of a reference site, which represent the outer boundaries of reference conditions.

The following methods may be used to determine reference conditions:

Primary Approach

- Comparing conditions in a waterbody to baseline data from minimally impaired waterbodies that are in a nearby watershed or in the same region having similar geology, hydrology, morphology, and/or riparian habitat.
- Evaluating historical data relating to condition of the waterbody in the past.
- Comparing conditions in a waterbody to conditions in another portion of the same waterbody, such as an unimpaired segment of the same stream.

Secondary Approach

- Reviewing literature (e.g. a review of studies of fish populations, etc., that were conducted on similar waterbodies that are least impaired).
- Seeking expert opinion (e.g. expert opinion from a regional fisheries biologist who has a good understanding of the waterbody’s fisheries health or potential).

- Applying quantitative modeling (e.g. applying sediment transport models to determine how much sediment is entering a stream based on land use information, etc.).

DEQ uses the primary approach for determining reference condition if adequate regional reference data are available and uses the secondary approach to estimate reference condition when there is no regional data. DEQ often uses more than one approach to determine reference condition, especially when regional reference condition data are sparse or nonexistent.

B3.2 Use of Statistics for Developing Reference Values or Ranges

Reference value development must consider natural variability as well as variability that can occur as part of field measurement techniques. Statistical approaches are commonly used to help incorporate variability. One statistical approach is to compare stream conditions to the mean (average) value of a reference data set to see if the stream condition compares favorably to this value or falls within the range of one standard deviation around the reference mean. The use of these statistical values assumes a normal distribution; whereas, water resources data tend to have a non-normal distribution (Helsel and Hirsch, 1995). For this reason, another approach is to compare stream conditions to the median value of a reference data set to see if the stream condition compares favorably to this value or falls within the range defined by the 25th and 75th percentiles of the reference data. This is a more realistic approach than using one standard deviation since water quality data often include observations considerably higher or lower than most of the data. Very high and low observations can have a misleading impact on the statistical summaries if a normal distribution is incorrectly assumed, whereas statistics based on non-normal distributions are far less influenced by such observations.

Figure B3-1 is an example boxplot type presentation of the median, 25th and 75th percentiles, and minimum and maximum values of a reference data set. In this example, the reference stream results are stratified by two different stream types. Typical stratifications for reference stream data may include Rosgen stream types, stream size ranges, or geology. If the parameter being measured is one where low values are undesirable and can cause harm to aquatic life, then measured values in the potentially impaired stream that fall below the 25th percentile of reference data are not desirable and can be used to indicate impairment. If the parameter being measured is one where high values are undesirable, then measured values above the 75th percentile can be used to indicate impairment.

The use of a non-parametric statistical distribution for interpreting narrative WQS or developing numeric criteria is consistent with EPA guidance for determining nutrient criteria (Helsel and Hirsch, 1995). Furthermore, the selection of the applicable 25th or 75th percentile values from a reference data set is consistent with ongoing DEQ guidance development for interpreting narrative WQS where it is determined that there is “good” confidence in the quality of the reference sites and resulting information (Suplee, 2004). If it is determined that there is only a “fair” confidence in the quality of the reference sites, then the 50th percentile or median value should be used, and if it is determined that there is “very high” confidence, then the 90th percentile of the reference data set should be used. Most reference data sets available for water quality restoration planning and related TMDL development, particularly those dealing with sediment and habitat alterations, would tend to be “fair” to “good” quality. This is primarily due to a the limited number of available reference sites/data points available after applying all potentially applicable stratifications on the data, inherent variations in monitoring results among field crews, the potential for variations in field methodologies, and natural yearly variations in stream systems often not accounted for in the data set.

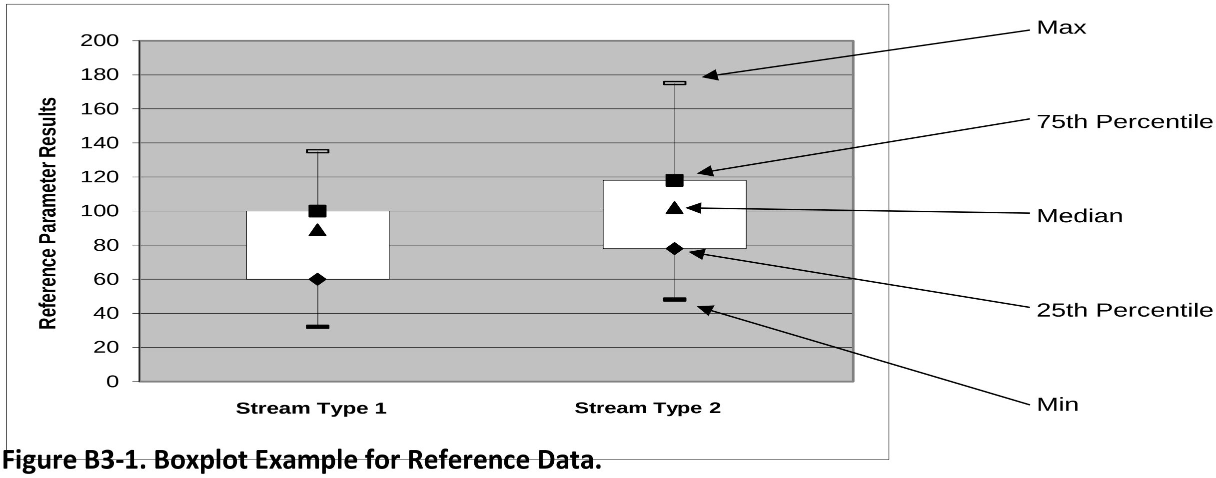


Figure B3-1. Boxplot Example for Reference Data.

The above 25th – 75th percentile statistical approach has several considerations:

1. It is a simple approach that is easy to apply and understand.
2. About 25% of all streams would naturally fall into the impairment range. Thus, it should not be applied unless there is some linkage to human activities that could lead to the observed conditions. Where applied, it must be noted that the stream's potential may prevent it from achieving the reference range as part of an adaptive management plan.
3. About 25% of all streams would naturally have a greater water quality potential than the minimum water quality bar represented by the 25th to 75th percentile range. This may represent a condition where the stream's potential has been significantly underestimated. Adaptive management can also account for these considerations.
4. Obtaining reference data that represents a naturally occurring condition can be difficult, particularly for larger waterbodies with multiple land uses within the drainage. This is because all reasonable land, soil, and water conservation practices may not be in place in many larger waterbodies across the region. Even if these practices are in place, the proposed reference stream may not have fully recovered from past activities, such as riparian harvest, where reasonable land, soil, and water conservation practices were not applied.
5. A stream should not be considered impaired unless there is a relationship between the parameter of concern and the beneficial use such that not meeting the reference range is likely to cause harm or other negative impacts to the beneficial use as described by the WQS in **Table B2-2**. In other words, if not meeting the reference range is not expected to negatively impact aquatic life, coldwater fish, or other beneficial uses, then an impairment determination should not be made based on the particular parameter being evaluated. Relationships that show an impact to the beneficial use can be used to justify impairment based on the above statistical approach.

As identified in (2) and (3) above, there are two types of errors that can occur due to this or similar statistical approaches where a reference range or reference value is developed: (1) A stream could be considered impaired even though the naturally occurring condition for that stream parameter does not meet the desired reference range or (2) a stream could be considered not impaired for the parameter(s) of concern because the results for a given parameter fall just within the reference range, whereas the naturally occurring condition for that stream parameter represents much higher water quality and beneficial uses could still be negatively impacted. The implications of making either of these errors can be used to modify the above approach, although the approach used will need to be protective of water quality to be consistent with DEQ guidance and WQS (Suplee, 2004). Either way, adaptive management is applied to this water quality plan and associated TMDL development to help address the above considerations.

Where the data does suggest a normal distribution, or reference data is presented in a way that precludes use of non-normal statistics, the above approach can be modified to include the mean plus or minus one standard deviation to provide a similar reference range with all of the same considerations defined above.

Options When Regional Reference Data is Limited or Does Not Exist

In some cases, there is very limited reference data and applying a statistical approach like above is not possible. Under these conditions, the limited information can be used to develop a reference value or range, with the need to note the greater level of uncertainty and perhaps a greater level of future monitoring as part of the adaptive management approach. These conditions can also lead to more reliance on secondary type approaches for reference development.

Another approach would be to develop statistics for a given parameter from all streams within a watershed or region of interest (U.S. Environmental Protection Agency, 2000). The boxplot distribution of all the data for a given parameter can still be used to help determine potential target values knowing that most or all of the streams being evaluated are either impaired or otherwise have a reasonable probability of having significant water quality impacts. Under these conditions you would still use the median and the 25^{th} or 75^{th} percentiles as potential target values, but you would use the 25^{th} and 75^{th} percentiles in a way that is opposite from how you use the results from a regional reference distribution. This is because you are assuming that, for the parameter being evaluated, as many as 50% to 75% of the results from the whole data distribution represent questionable water quality. **Figure B3-2** is an example statistical distribution of an entire dataset where lower values represent better water quality (and reference data are limited). In **Figure B3-2**, the median and 25^{th} percentiles of all data represent potential target values versus the median and 75^{th} percentiles discussed above for regional reference distribution. Whether you use the median, the 25^{th} percentile, or both should be based on an assessment of how impacted all the measured streams are in the watershed. Additional consideration of target achievability is important when using this approach. Also, there may be a need to also rely on secondary reference development methods to modify how you apply the target and/or to modify the final target value(s). Your certainty regarding indications of impairment may be lower using this approach, and you may need to rely more on adaptive management as part of TMDL implementation.

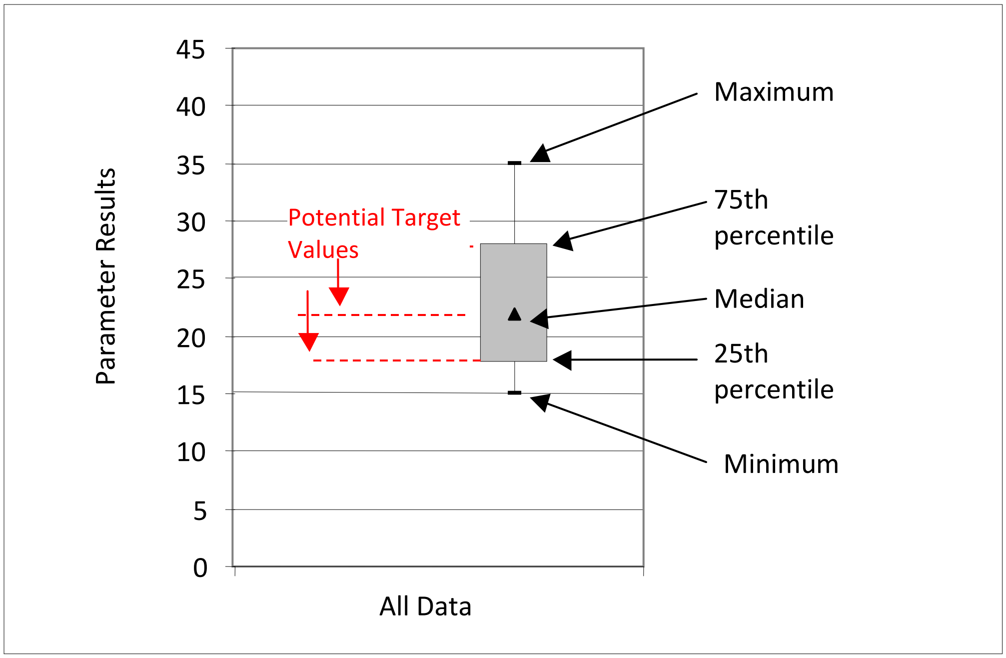


Figure B3-2. Boxplot example for the use of all data to set targets.

4.0 References

Helsel, Dennis R. and Robert M. Hirsch. 1995. Statistical Methods in Water Resources Studies in Environmental Science, Vol. 49, Amsterdam, The Netherlands: Elsevier Science Publishers B.V.

Montana Department of Environmental Quality. 2012. Circular DEQ-7: Montana Numeric Water Quality Standards. Helena, MT: Montana Department of Environmental Quality. http://deq.mt.gov/wqinfo/Circulars.mcpx. Accessed 1/15/2013.

Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau. 2012. Montana 2012 Final Water Quality Integrated Report. Helena, MT: Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau. WQPBIMTSR-004f.

Suplee, Michael W. 2004. Wadeable Streams of Montana's Hi-Line Region: An Analysis of Their Nature and Condition With an Emphasis on Factors Affecting Aquatic Plant Communities and Recommendations to Prevent Nuisance Algae Conditions. Helena, MT: Montana Department of Environmental Quality, Water Quality Standards Section.

Suplee, Michael W., Vicki Watson, Arun Varghese, and Joshua Cleland. 2012. Scientific and Technical Basis of the Numeric Nutrient Criteria for Montana's Wadeable Streams and Rivers: Update 1 Draft. Helena, MT: Montana Department of Environmental Quality.

U.S. Environmental Protection Agency. 2000. Nutrient Criteria Technical Guidance Manual: Rivers and Streams. Washington, DC: Office of Science and Techology. EPA-822-B-00-002.

APPENDIX C – METALS AND NUTRIENT DATA

C1.0 METALS DATA

Table C-1. Surface water metals data for the Bitterroot River lower segment (MT76H001_030)

Waterbody	Site ID	Sample Date	Org.	Hardness (mg/L)	Flow (cfs)	pH	Al (D)	As (T)	As (TR)	Cd (TR)	Cr (TR)	Cu (TR)	Fe (TR)	Pb (T)	Pb (TR)	Hg (T)	Ni (TR)	Se (TR)	Ag (TR)	Zn (TR)
Bitterroot River (030)	12352500	3/16/2004	USGS	47.8	1,060	8.2	--	<2	--	0.033	<0.8	13.7	--	0.97	--	--	0.56	--	--	2
Bitterroot River (030)	12352500	6/24/2004	USGS	23.9	4,340	7.6	--	<2	--	<0.04	<0.8	1	--	0.14	--	--	0.21	--	--	1
Bitterroot River (030)	C05BITTR01	7/27/2004	DEQ	77.031	750	6.97	--	--	<1	<0.1	<1	1	90	--	2	--	<10	<1	<1	1
Bitterroot River (030)	CFRPO-19	1/18/2005	TSWQC	65.4	--	7.57	--	--	<1	<0.1	--	<1	--	--	<1	--	--	--	--	1.5
Bitterroot River (030)	CFRPO-19	2/15/2005	TSWQC	54.2	--	8.42	--	--	2	<0.1	--	2	--	--	<1	--	--	--	--	<0.5
Bitterroot River (030)	CFRPO-19	3/15/2005	TSWQC	50.7	--	8.3	--	--	<1	<0.1	--	<1	--	--	<1	--	--	--	--	<0.5
Bitterroot River (030)	CFRPO-19	4/13/2005	TSWQC	47.4	--	8.41	--	--	<1	<0.1	--	1	--	--	<1	--	--	--	--	<0.5
Bitterroot River (030)	12352500	4/20/2005	USGS	41.8	1,350	8	--	<2	--	<0.04	<0.8	1	--	0.25	--	--	0.44	--	--	2
Bitterroot River (030)	CFRPO-19	5/16/2005	TSWQC	24.2	--	7.42	--	--	2	--	--	2	--	--	--	--	--	--	--	4.7
Bitterroot River (030)	CFRPO-19	6/22/2005	TSWQC	28.6	--	8.43	--	--	1	--	--	1	--	--	--	--	--	--	--	1.8
Bitterroot River (030)	12352500	6/22/2005	USGS	25.3	4,860	7.9	--	<2	--	<0.04	<0.8	1	--	0.25	--	--	0.25	--	--	2
Bitterroot River (030)	CFRPO-19	7/19/2005	TSWQC	73	--	8.9	--	--	<1	<0.08	--	1	--	--	<0.5	--	--	--	--	0.9
Bitterroot River (030)	C05BITTR01	8/3/2005	DEQ	90.9	600	7.58	--	--	2	<0.08	< 1	< 1	110	--	<0.5	--	<10	<1	<1	<1
Bitterroot River (030)	CFRPO-19	8/16/2005	TSWQC	85.1	--	9.31	--	--	1	<0.08	--	2	--	--	<0.5	--	--	--	--	0.7
Bitterroot River (030)	CFRPO-19	9/13/2005	TSWQC	82.8	--	9.26	--	--	<1	<0.08	--	2	--	--	<0.5	--	--	--	--	1.1
Bitterroot River (030)	CFRPO-19	10/13/2005	TSWQC	82.4	--	--	--	--	<1	<0.08	--	<1	--	--	<0.5	--	--	--	--	<0.5
Bitterroot River (030)	CFRPO-19	11/15/2005	TSWQC	69.4	--	--	--	--	<1	<0.08	--	<1	--	--	<0.5	--	--	--	--	<0.5
Bitterroot River (030)	CFRPO-19	12/13/2005	TSWQC	70.8	--	--	--	--	<1	<0.08	--	<1	--	--	<0.5	--	--	--	--	<0.5
Bitterroot River (030)	12352500	4/6/2006	USGS	39.9	2,200	7.8	--	0.63	--	<0.04	--	1.9	1,020	0.88	--	--	--	--	--	4
Bitterroot River (030)	12352500	4/20/2006	USGS	35.1	3,320	7.7	--	0.44	--	<0.04	--	1.1	351	0.27	--	--	--	--	--	1
Bitterroot River (030)	12352500	5/3/2006	USGS	23.9	5,930	7.8	--	0.48	--	<0.04	--	1.3	553	0.49	--	--	--	--	--	3
Bitterroot River (030)	12352500	5/17/2006	USGS	15.7	10,500	7.4	--	0.62	--	0.031	--	4	2,010	1.89	--	--	--	--	--	8
Bitterroot River (030)	12352500	5/24/2006	USGS	16.3	13,800	7.4	--	0.42	--	<0.04	--	2.1	741	0.74	--	--	--	--	--	3
Bitterroot River (030)	12352500	6/1/2006	USGS	25	6,260	7.6	--	0.43	--	<0.04	--	1.4	405	0.36	--	--	--	--	--	2
Bitterroot River (030)	12352500	6/14/2006	USGS	18.8	8,450	7.5	--	0.38	--	<0.04	0.45	1.1	355	0.32	--	--	0.39	--	--	3
Bitterroot River (030)	12352500	6/20/2006	USGS	24.9	5,000	7.7	--	0.4	--	<0.04	--	0.9	238	0.21	--	--	--	--	--	1
Bitterroot River (030)	12352500	6/27/2006	USGS	27.5	3,290	7.7	--	0.36	--	<0.04	--	0.9	133	0.12	--	--	--	--	--	<2
Bitterroot River (030)	12352500	9/27/2006	USGS	69.6	670	7.8	--	0.55	--	<0.04	--	0.7	73.5	0.05	--	--	--	--	--	<2
Bitterroot River (030)	12352500	10/18/2006	USGS	78	657	8.2	--	0.58	--	<0.018	--	1	63.1	<0.06	--	--	--	--	--	<2
Bitterroot River (030)	12352500	3/22/2007	USGS	29.5	2,760	6.6	--	0.29	--	0.013	<0.6	0.9	--	0.16	--	--	0.27	--	--	1
Bitterroot River (030)	12352500	4/10/2007	USGS	28.4	2,860	7.7	--	0.31	--	0.01	--	0.93	359	0.3	--	--	--	--	--	1.6
Bitterroot River (030)	12352500	4/24/2007	USGS	34.7	2,150	7.6	--	0.31	--	0.01	--	0.83	196	0.16	--	--	--	--	--	1.1
Bitterroot River (030)	12352500	5/4/2007	USGS	18.3	7,800	7.6	--	0.39	--	0.01	--	1.6	785	0.7	--	--	--	--	--	3.3
Bitterroot River (030)	12352500	5/15/2007	USGS	19.2	7,760	7.5	--	0.32	--	0.01	--	1.3	442	0.42	--	--	--	--	--	2.9
Bitterroot River (030)	12352500	5/23/2007	USGS	24.5	6,600	7.5	--	0.34	--	<0.018	--	0.92	304	0.25	--	--	--	--	--	2
Bitterroot River (030)	12352500	6/1/2007	USGS	24.3	5,130	7.6	--	0.32	--	<0.018	--	0.67	214	0.16	--	--	--	--	--	1.2
Bitterroot River (030)	12352500	6/13/2007	USGS	27	5,580	7.8	--	0.42	--	<0.018	<0.6	1.2	290	0.22	--	--	0.26	--	--	2.4
Bitterroot River (030)	12352500	6/20/2007	USGS	32.9	3,480	7.6	--	0.37	--	0.01	--	1	191	0.15	--	--	--	--	--	2.1
Bitterroot River (030)	12352500	6/27/2007	USGS	37.1	2,150	7.8	--	0.44	--	<0.018	--	0.62	121	0.08	--	--	--	--	--	1.1
Bitterroot River (030)	12352500	3/10/2008	USGS	65.4	833	8.2	--	0.45	--	<0.014	--	<1.2	124	0.12	--	--	--	--	--	<2
Bitterroot River (030)	12352500	3/25/2008	USGS	61.2	889	7.6	--	0.45	--	<0.014	--	<1.2	184	0.2	--	--	--	--	--	<2
Bitterroot River (030)	12352500	4/1/2008	USGS	63.5	833	7.8	--	0.43	--	<0.014	--	0.7	133	0.07	--	--	--	--	--	<2
Bitterroot River (030)	12352500	4/9/2008	USGS	60.4	786	7.9	--	0.46	--	0.007	--	<1.2	148	0.12	--	--	--	--	--	<2
Bitterroot River (030)	12352500	4/17/2008	USGS	35.4	1,920	7.7	--	0.54	--	0.017	--	1.4	565	0.51	--	--	--	--	--	2.8
Bitterroot River (030)	12352500	4/23/2008	USGS	39.7	1,700	7.4	--	0.4	--	<0.014	--	0.81	286	0.25	--	--	--	--	--	1.5

Table C-1. Surface water metals data for the Bitterroot River lower segment (MT76H001_030)

Waterbody	Site ID	Sample Date	Org.	Hardness (mg/L)	Flow (cfs)	pH	Al (D)	As (T)	As (TR)	Cd (TR)	Cr (TR)	Cu (TR)	Fe (TR)	Pb (T)	Pb (TR)	Hg (T)	Ni (TR)	Se (TR)	Ag (TR)	Zn (TR)
Bitterroot River (030)	12352500	4/30/2008	USGS	34.6	2,580	7.8	--	0.57	--	0.01	--	1.6	794	0.65	--	--	--	--	--	3.6
Bitterroot River (030)	12352500	5/6/2008	USGS	28	3,560	7.6	--	0.59	--	0.011	--	1.6	848	0.77	--	--	--	--	--	4.2
Bitterroot River (030)	12352500	5/13/2008	USGS	27.4	4,040	7.9	--	0.4	--	<0.014	--	0.94	308	0.3	--	--	--	--	--	2.2
Bitterroot River (030)	12352500	5/20/2008	USGS	15.4	17,200	7.2	--	0.7	--	0.025	--	4.7	1,960	1.89	--	--	--	--	--	8.7
Bitterroot River (030)	12352500	5/24/2008	USGS	21.1	12,400	7.5	--	0.47	--	0.016	--	2.7	635	0.73	--	--	--	--	--	3.8
Bitterroot River (030)	12352500	6/3/2008	USGS	17.8	12,600	7.4	--	0.55	--	<0.014	0.67	1.8	693	0.74	--	--	0.58	--	--	5.1
Bitterroot River (030)	12352500	6/11/2008	USGS	23.1	8,540	7.7	--	0.48	--	<0.014		1.2	435	0.38	--	--	--	--	--	2
Bitterroot River (030)	12352500	6/25/2008	USGS	19.8	12,000	7.5	--	0.42	--	0.012		1.1	486	0.43	--	--	--	--	--	2.1
Bitterroot River (030)	12352500	3/3/2009	USGS	58.7	1,000	7.8	--	0.41	--	<0.06	<0.4	<4	129	0.12	--	--	0.14	--	--	<2
Bitterroot River (030)	12352500	3/17/2009	USGS	58.7	1,020	7.6	--	0.37	--	<0.06	--	<4	116	0.19	--	--	--	--	--	4.3
Bitterroot River (030)	12352500	3/26/2009	USGS	45.4	1,300	8.1	--	0.34	--	<0.06	--	--	159	0.15	--	--	--	--	--	<2
Bitterroot River (030)	12352500	4/1/2009	USGS	49.1	1,210	7.7	--	0.33	--	<0.06	--	<4	140	0.09	--	--	--	--	--	9
Bitterroot River (030)	12352500	4/15/2009	USGS	36.3	2,700	7.8	--	0.4	--	<0.06	--	--	456	0.35	--	--	--	--	--	6.7
Bitterroot River (030)	12352500	4/22/2009	USGS	27	4,540	7.5	--	0.66	--	<0.06	--	2.4	1,650	1.32	--	--	--	--	--	5.8
Bitterroot River (030)	12352500	5/5/2009	USGS	32.2	3,490	7.8	--	0.32	--	0.037	--	--	338	0.36	--	--	--	--	--	2.8
Bitterroot River (030)	12352500	5/12/2009	USGS	28.9	4,560	7.7	--	0.38	--	<0.06	--	--	286	0.31	--	--	--	--	--	2
Bitterroot River (030)	12352500	5/19/2009	USGS	18.4	9,260	7.5	--	0.83	--	<0.06	--	3.9	2,310	2.37	--	--	--	--	--	9.9
Bitterroot River (030)	12352500	5/27/2009	USGS	18.8	15,900	7.5	--	0.51	--	<0.06	--	2.2	785	0.93	--	--	--	--	--	3.6
Bitterroot River (030)	12352500	6/1/2009	USGS	17.1	17,800	7.4	--	0.47	--	<0.06	--	2	780	0.88	--	--	--	--	--	3.8
Bitterroot River (030)	12352500	6/9/2009	USGS	23	9,260	7.6	--	0.44	--	<0.06	--	--	543	0.6	--	--	--	--	--	3
Bitterroot River (030)	12352500	6/16/2009	USGS	19.2	9,310	7.6	--	0.37	--	<0.06	--	--	572	0.58	--	--	--	--	--	2.7
Bitterroot River (030)	12352500	6/24/2009	USGS	26.5	6,720	7.7	--	0.5	--	<0.06	0.32	--	283	0.26	--	--	0.39	--	--	2.6
Bitterroot River (030)	C05BITTR01	6/6/2012	DEQ	20	--	7.9	40	--	<3	<0.08	< 1	1	520	--	0.5	<0.005	--	<1	<0.5	<10
Bitterroot River (030)	C05BITTR01	8/24/2012	DEQ	76	--	8.63	<30	--	<3	<0.08	< 1	1	50	--	<0.5	<0.005	--	<1	<0.5	<10
Bitterroot River (030)	C05BITTR25	9/21/2012	DEQ	88	623	8.57	<30	--	<3	<0.08	<1	<1	<50	--	<0.5	<0.005	--	<1	<0.5	<10

Metals are in micrograms per liter (µg/L)
D = dissolved, T = total, TR = total recoverable

Table C-2.Surface water metals data for various tributaries and the Bitterroot River middle segment (MT76H001_020)

Waterbody	Site ID	Sample Date	Org.	Hardness (mg/L)	Flow (cfs)	pH	Al (D)	As (T)	As (TR)	Cd (TR)	Cr (TR)	Cu (TR)	Fe (TR)	Pb (T)	Pb (TR)	Pb (D)	Hg (T)	Ni (TR)	Se (TR)	Ag (TR)	Zn (TR)
One Horse Creek	One Horse Creek	8/21/1997	MBMG	26.05	--	6.92	--	--	--	--	--	--	--	--	--	<2	--	--	--	--	--
One Horse Creek	One Horse Creek	8/22/1997	MBMG	37.68	--	7.04	--	--	--	--	--	--	--	--	--	<2	--	--	--	--	--
One Horse Creek	One Horse Creek	10/6/1997	MBMG	16.35	--	7.63	--	--	--	--	--	--	--	--	--	12.7	--	--	--	--	--
Bitterroot River (020)	12351200	3/15/2004	USGS	42	962	8.1	3.6	<2	--	<0.04	<0.8	1	--	0.08	--	--	--	0.35	--	--	<2
Bitterroot River (020)	12351200	6/23/2004	USGS	21.5	3,910	7.6	--	<2	--	<0.04	<0.8	0.9	--	0.16	--	--	--	0.35	--	--	2
Miller Creek	C05MILRC02	7/8/2004	DEQ	94	2.29	8.37	<100	--	<3	<0.1	<1	<1	20	--	<0.5	--	--	<20	<1	<3	<10
Miller Creek	C05MILRC01	7/8/2004	DEQ	143	3.5	7.72	<100	--	<3	<0.1	<1	<1	20	--	<0.5	--	--	<20	<1	<3	<10
Bitterroot River (020)	12351200	4/21/2005	USGS	40.8	972	7.5	--	<2	--	<0.04	<0.8	0.6	--	0.18	--	--	--	0.26	--	--	1
Bitterroot River (020)	12351200	6/23/2005	USGS	23.2	4,360	7.9	--	<2	--	<0.04	0.5	1.3	--	0.34	--	--	--	0.31	--	--	2
Lolo Creek	C05LOLOC01	6/23/2005	DEQ	31.8	81.38	--	30	--	1	<0.08	<1	<1	110	--	<0.5	--	<0.1	<10	<1	<1	<1
Lolo Creek	C05LOLOC02	6/23/2005	DEQ	19.6	267.95	--	30	--	1	<0.08	<1	<1	80	--	<0.5	--	<0.1	<10	<1	<1	<1
Bitterroot River (020)	12351200	4/19/2006	USGS	29.2	2,820	7.7	--	0.36	--	<0.04	0.23	1.4	--	0.34	--	--	--	0.24	--	--	2
Bitterroot River (020)	12351200	6/15/2006	USGS	17.6	7,080	7.4	--	0.35	--	<0.04	0.3	0.9	--	0.28	--	--	--	0.32	--	--	2
Bitterroot River (020)	12351200	3/22/2007	USGS	27.1	2,290	7.8	--	0.32	--	0.014	<0.6	1	--	0.21	--	--	--	0.21	--	--	2
Bitterroot River (020)	12351200	6/14/2007	USGS	21.7	4,600	7.7	--	0.37	--	<0.018	<0.6	0.83	--	0.24	--	--	--	0.2	--	--	2.8
Miller Creek	C05MILRC01	7/11/2007	DEQ	--	3.013	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Miller Creek	C05MILRC03	7/11/2007	DEQ	--	9.664	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Miller Creek	C05MILRC04	7/11/2007	DEQ	--	6.645	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table C-2.Surface water metals data for various tributaries and the Bitterroot River middle segment (MT76H001_020)

Waterbody	Site ID	Sample Date	Org.	Hardness (mg/L)	Flow (cfs)	pH	Al (D)	As (T)	As (TR)	Cd (TR)	Cr (TR)	Cu (TR)	Fe (TR)	Pb (T)	Pb (TR)	Pb (D)	Hg (T)	Ni (TR)	Se (TR)	Ag (TR)	Zn (TR)
Miller Creek	C05MILRC04	10/9/2007	DEQ	--	0.773	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bitterroot River (020)	12351200	4/2/2008	USGS	55.5	686	7.8	--	0.41	--	<0.014	<0.4	0.63	--	0.07	--	--	--	0.16	--	--	<2
Bitterroot River (020)	12351200	6/4/2008	USGS	18.3	9,780	7.4	--	0.41	--	0.015	0.57	1.8	--	0.6	--	--	--	0.42	--	--	3.1
Bitterroot River (020)	12351200	3/3/2009	USGS	48.3	885	7.6	--	0.36	--	<0.06	<0.4	<4	--	0.09	--	--	--	0.13	--	--	1.3
Bitterroot River (020)	12351200	6/25/2009	USGS	23.6	5,420	7.6	--	0.46	--	0.031	0.26	<4	--	0.42	--	--	--	0.27	--	--	3.6
Miller Creek	BTR-MILLER1	8/9/2010	WTRSD	--	0.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Miller Creek	BTR-MILLER2	8/9/2010	WTRSD	--	2.18	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bitterroot River (020)	C05BITRR23	6/5/2012	DEQ	14	--	8.1	50	--	<3	<0.08	<1	1	370	--	<0 .5	--	<0.005	--	<1	<0.5	<10
Bitterroot River (020)	C05BITRR24	6/5/2012	DEQ	14	--	7.9	310	--	<3	<0.08	<1	<1	<50	--	<0 .5	--	<0.005	--	<1	<0.5	<10
Bitterroot River (020)	C05BITRR31	6/6/2012	DEQ	17	--	8	60	--	<3	<0.08	<1	1	450	--	<0 .5	--	<0.005	--	<1	<0.5	<10
Miller Creek	C05MILRC04	6/6/2012	DEQ	91	16.96	8.7	<30	--	<3	<0.08	<1	<1	290	--	<0.5	--	--	--	<1	<0.5	<10
Bitterroot River (020)	C05BITRR31	8/8/2012	DEQ	61	--	--	<30	--	<3	<0.08	<1	<1	70	--	<0 .5	--	<0.005	--	<1	<0.5	<10
Bitterroot River (020)	C05BITRR23	8/13/2012	DEQ	34	--	8.7	<30	--	<3	<0.08	<1	1	80	--	<0 .5	--	<0.005	--	<1	<0.5	<10
Bitterroot River (020)	C05BITRR24	8/13/2012	DEQ	41	--	7.8	<30	--	<3	<0.08	<1	1	<50	--	<0 .5	--	<0.005	--	<1	<0.5	<10
Miller Creek	C05MILRC01	8/27/2012	DEQ	158	1.94	8.34	<30	--	<3	<0.08	<1	<1	<50	--	<0.5	--	--	--	<1	<0.5	<10
Miller Creek	C05MILRC06	8/27/2012	DEQ	--	0.19	8.16	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Miller Creek	C05MILRC04	8/27/2012	DEQ	--	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bitterroot River (020)	C05BITRR24	9/14/2012	DEQ	48	270	7.84	<30	--	<3	<0.08	<1	1	<50	--	<0 .5	--	<0.005	--	<1	<0.5	<10
Bitterroot River (020)	C05BITRR31	9/14/2012	DEQ	70	--	8.03	<30	--	<3	<0.08	<1	1	50	--	<0 .5	--	<0.005	--	<1	<0.5	<10
Bitterroot River (020)	C05BITRR33	9/14/2012	DEQ	38	--	9.44	<30	--	<3	<0.08	<1	1	100	--	<0 .5	--	<0.005	--	<1	<0.5	<10
Miller Creek	C05MILRC01	9/30/2012	DEQ	102	1.16	8.57	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Miller Creek	C05MILRC07	9/30/2012	DEQ	102	2.8	8.83	<30	--	<3	<0.08	<1	<1	<50	--	<0.5	--	--	--	<1	<0.5	<10

Metals are in micrograms per liter (µg/L)
D = dissolved, T = total, TR = total recoverable

Table C-3. Recent sediment metals data for the Bitterroot River lower segment (MT76H001_030) and related samples

Waterbody	Site ID	Sample Date	Organization	As (TR)	Cd (TR)	Cr (TR)	Cu (TR)	Fe (TR)	Pb (TR)	Hg (T)	Zn (TR)
Bitterroot River (030)	12352500	8/10/1998	USGS	2.6	0.2	40	26	--	49	0.09	94
Bitterroot River (030)	12352500	8/11/1999	USGS	4.2	0.2	38	30	--	53	0.04	110
Bitterroot River (030)	C05BITTR01	8/22/2001	DEQ	<5	<1	11	17	12,900	15	--	66
O'Brien Creek	C05OBINC01	6/17/2006	DEQ	2.06	<0.5	6.4	15.4	6,000	4.48	--	16.4

Metals are in micrograms per gram (µg/g)
T = total, TR = total recoverable

Table C-4. Surface water metals data for the Lick Creek and related samples

Waterbody	Site ID	Sample Date	Org.	Hardness (mg/L)	Flow (cfs)	pH	Al (D)	As (TR)	Cd (TR)	Cr (TR)	Cu (TR)	Fe (TR)	Pb (TR)	Ni (TR)	Se (TR)	Ag (TR)	Zn (TR)
Lick Creek	C05LICKC10	7/14/2004	DEQ	9	1	3.96	--	<3	--	<1	<1	50	<0.5	<20	<1	<3	<10
Lick Creek	C05LICKC20	7/14/2004	DEQ	10	5	3.6	--	<3	--	1	<1	290	<0.5	<20	<1	<3	<10
Lick Creek	C05LICKC01	6/4/2012	DEQ	12	16.9	7.9	320	<3	<0.08	1	2	1,780	1.2	--	<1	<0.5	<10
Lick Creek	C05LICKC01	8/8/2012	DEQ	15	5.54	7.5	140	<3	<0.08	<1	<1	500	<0.5	--	<1	<0.5	<10
Lick Creek	C05LICKC01	9/20/2012	DEQ	15	2.65	7.65	70	<3	<0.08	<1	<1	260	<0.5	--	<1	<0.5	<10
Lick Creek	C05LICKC01	6/14/2013	DEQ	10.1	12.92	7.2	776	<3	<0.08	<1	<1	520	0.3	<20	<1	<0.5	<10
Lick Creek	C05LICKC03	6/14/2013	DEQ	7.3	3.39	7.44	41	<3	<0.08	<1	<1	60	<0.5	<20	<1	<0.5	<10
Lick Creek	C05LICKC01	7/24/2013	DEQ	12	5.2	7.05	297	<3	<0.08	<1	<1	520	<0.5	<20	<1	<0.5	<10
Lick Creek	C05LICKC03	7/24/2013	DEQ	10	0.31	6.74	46	<3	<0.08	<1	<1	250	0.5	<20	<1	<0.5	<10
Lick Creek	C05LICKC01	9/3/2013	DEQ	14	2.25	6.46	198	<3	<0.08	<1	<1	310	<0.5	<20	<1	<0.5	<10
Lick Creek	C05LICKC02	9/3/2013	DEQ	14	3.73	6.75	146	<3	<0.08	<1	<1	270	<0.5	<20	<1	<0.5	<10
Lick Creek	C05LICKC03	9/3/2013	DEQ	12	0.4	6.27	58	<3	<0.08	<1	<1	120	<0.5	<20	<1	<0.5	<10

Table C-4. Surface water metals data for the Lick Creek and related samples

Waterbody	Site ID	Sample Date	Org.	Hardness (mg/L)	Flow (cfs)	pH	Al (D)	As (TR)	Cd (TR)	Cr (TR)	Cu (TR)	Fe (TR)	Pb (TR)	Ni (TR)	Se (TR)	Ag (TR)	Zn (TR)
Lolo WWTP Outfall	C05LWWTP01	7/24/2013	EPA	209	0.17	6.82	<9	<1	0.05	<1	5	50	0.8	--	<1	0.4	74
Lolo WWTP Outfall	C05LWWTP01	9/3/2013	EPA	225	0.3	6.59	<9	<1	0.05	<1	8	30	0.6	--	<1	<0.3	69
Lost Horse Creek Canal	C05LHCCN01	6/14/2013	DEQ	2.5	41.74	7.27	55	<1	<0.03	<1	<1	20	<0.3	--	<1	<0.2	<5
Lost Horse Creek Canal	C05LHCCN01	7/24/2013	EPA	5	3.37	6.94	38	<1	<0.03	<1	<1	<20	<0.3	--	<1	<0.2	<8
Lost Horse Creek Canal	C05LHCCN01	9/3/2013	EPA	5	2.22	6.77	25	<1	<0.03	<1	<1	<20	<0.3	--	<1	<0.2	<8
Tin Cup Creek	C05TINCC04	6/5/2012	DEQ	4	323.85	8.4	60	<3	<0.08	<1	<1	60	<0.5	--	<1	<0.5	<10
Tin Cup Creek	C05TINCC05	8/21/2012	DEQ	9	6.3	8.4	<30	<3	<0.08	<1	<1	<50	<0.5	--	<1	<0.5	<10
Tin Cup Creek	C05TINCC05	9/20/2012	DEQ	11	3.3	8.19	<30	<3	<0.08	<1	<1	<50	<0.5	--	<1	<0.5	<10
Tin Cup Creek	C05TINCC03	7/26/2013	DEQ	5.1	33.25	7.67	19	<1	<0.03	<1	<1	10	<0.3	--	<1	<0.2	<5
Unnamed Tributary	C05LICKT01	6/14/2013	DEQ	49	0.1	7.62	446	1	<0.03	<1	1	420	0.3	--	<1	<0.2	<5
Unnamed Tributary	C05LICKT01	7/24/2013	EPA	--	0	--	--	--	--	--	--	--	--	--	--	--	--
Unnamed Tributary	C05LICKT01	9/3/2013	EPA	--	0	--	--	--	--	--	--	--	--	--	--	--	--

Metals are in micrograms per liter (µg/L)
D = dissolved, TR = total recoverable

Table C-5. Sediment metals data for Lick Creek and related samples

Waterbody	Site ID	Sample Date	Organization	As (TR)	Cd (TR)	Cr (TR)	Cu (TR)	Fe (TR)	Pb (TR)	Hg (T)	Zn (TR)
Lick Creek	C05LICKC03	9/3/2013	EPA	2.1	0.23	26	13.8	13,200	233	<0.50	62
Lick Creek	C05LICKC01	9/3/2013	EPA	2.7	0.09	7.7	13.7	9,810	42.1	<0.50	52
Lost Horse Creek Canal	C05LHCCN01	9/3/2013	EPA	1.8	0.17	17.7	7.9	14,500	161	<0.50	66

Metals are in micrograms per gram (µg/g)
T = total, TR = total recoverable

C2.0 Nutrient Data

Table C-6. Surface Water Nutrient Data for the Bitterroot Project AreaNutrient data

Org ID	Waterbody Name	Site ID	Latitude	Longitude	Collection Date	Flow (cfs)	TN (mg/L)	TP (mg/L)	NN (mg/L)	Chlor-*a* (mg/m2)	AFDM (g/m2)
TSWQC_WQX	Ambrose Creek	THMAMBUSFS-3	46.54208	-113.91695	7/31/2003			0.04	0.068		
TSWQC_WQX	Ambrose Creek	THMAMBUSFS-3	46.54208	-113.91695	7/25/2006			0.034	0.066		
TSWQC_WQX	Ambrose Creek	THMAMBUSFS-3	46.54208	-113.91695	8/2/2007		0.25	0.028	0.063		
TSWQC_WQX	Ambrose Creek	THMAMBUSFS-3	46.54208	-113.91695	8/27/2007		0.12	0.02	0.059		
MDEQ_WQ-WQX	Ambrose Creek	C05AMBRC03	46.54189	-113.91756	8/8/2012	0.6	0.13	< 0.01	0.043		
MDEQ_WQ-WQX	Ambrose Creek	C05AMBRC03	46.54189	-113.91756	9/20/2012	0.3	0.06	0.04	0.043		
MDEQ_WQ-WQX	Ambrose Creek	C05AMBRC05	46.55864	-113.99641	8/30/2012	1.21	0.4	0.07	0.15	23.6	6.31
MDEQ_WQ-WQX	Ambrose Creek	C05AMBRC05	46.55864	-113.99641	9/28/2012	E 0.1	0.53	< 0.01	0.195	10.9	5.44
TSWQC_WQX	Ambrose Creek	THMAMBPARK-2	46.5579	-113.99683	7/31/2003			0.21	0.291		
MDEQ_WQ-WQX	Ambrose Creek	C05AMBRC06	46.56069	-114.02348	8/30/2012	1.03	0.38	0.03	0.157	5.8	
MDEQ_WQ-WQX	Ambrose Creek	C05AMBRC06	46.56069	-114.02348	9/28/2012	E 0.1	0.98	0.45	0.127		
MTWTRSHD_WQX	Ambrose Creek	BTR-AMBROSE1	46.56074	-114.02373	8/7/2010	0.23	0.57	0.07	0.18	E <50	
TSWQC_WQX	Ambrose Creek	THMAMBCONFL-1	46.56452	-114.03505	7/31/2003			0.19	0.337		
TSWQC_WQX	Ambrose Creek	THMAMBCONFL-1	46.56452	-114.03505	7/24/2006			0.332	0.375		
TSWQC_WQX	Ambrose Creek	THMAMBCONFL-1	46.56452	-114.03505	8/2/2007		0.69	0.113	0.195		
TSWQC_WQX	Ambrose Creek	THMAMBCONFL-1	46.56452	-114.03505	8/27/2007		0.52	0.013	0.15		
MDEQ_WQ-WQX	Ambrose Creek	C05AMBRC04	46.56452	-114.03505	8/29/2012		0.8	0.41	0.157		
MDEQ_WQ-WQX	Ambrose Creek	C05AMBRC04	46.56452	-114.03505	9/28/2012	E 1.0	4.91	4.23	0.142		
TSWQC_WQX	Bass Creek	BASSUSFS	46.57383	-114.14912	8/1/2007		0.2	0.007	0.003		
TSWQC_WQX	Bass Creek	BASSUSFS	46.57383	-114.14912	8/28/2007		0.048	0.013	0.002		

Table C-6. Surface Water Nutrient Data for the Bitterroot Project AreaNutrient data

Org ID	Waterbody Name	Site ID	Latitude	Longitude	Collection Date	Flow (cfs)	TN (mg/L)	TP (mg/L)	NN (mg/L)	Chlor-*a* (mg/m2)	AFDM (g/m2)
MDEQ_WQ-WQX	Bass Creek	C05BASSC10	46.57366	-114.14642	7/9/2004	E 45		< 0.01	< 0.001		
MDEQ_WQ-WQX	Bass Creek	C05BASSC01	46.5745	-114.1344	8/2/2007		0.12	0.005	< 0.001	3.81	
MDEQ_WQ-WQX	Bass Creek	C05BASSC01	46.5745	-114.1344	8/14/2012	9.82	< 0.05	< 0.01	< 0.003		
MDEQ_WQ-WQX	Bass Creek	C05BASSC01	46.5745	-114.1344	9/14/2012	4.77	< 0.05	< 0.01	< 0.003		
MDEQ_WQ-WQX	Bass Creek	C05BASSC04	46.57647	-114.11008	8/14/2012	0.25	0.23	< 0.01	0.029	35.2	16.5
MDEQ_WQ-WQX	Bass Creek	C05BASSC04	46.57647	-114.11008	9/14/2012	0.12			0.01		
MDEQ_WQ-WQX	Bass Creek	C05BASSC20	46.57577	-114.09946	7/9/2004	E 0.75		0.01	0.037		
MDEQ_WQ-WQX	Bass Creek	C05BASSC20	46.57577	-114.09946	8/14/2012	0.8	0.24	< 0.01	0.022	31.9	22.0
MDEQ_WQ-WQX	Bass Creek	C05BASSC20	46.57577	-114.09946	9/14/2012	0.42	0.17		0.015		
MDEQ_WQ-WQX	Bass Creek	C05BASSC02	46.5741	-114.0945	8/14/2012	2.1	0.81	< 0.01	0.152		
MDEQ_WQ-WQX	Bass Creek	C05BASSC02	46.5741	-114.0945	9/14/2012	1.06	0.26	0.04	0.031		
TSWQC_WQX	Bass Creek	BASS93S	46.5739	-114.09414	8/1/2007		0.6	0.018	0.089		
TSWQC_WQX	Bass Creek	BASS93S	46.5739	-114.09414	8/28/2007		0.33	0.013	0.058		
MDEQ_WQ_WQX	Lick Creek	C05LICKC10	46.07583	-114.25534	7/14/2004	E 1		< 0.01	0.031		
TSWQC_WQX	Lick Creek	LICKUSFS5621	46.07609	-114.25374	6/26/2007		< 0.01	< 0.005	0.02		
TSWQC_WQX	Lick Creek	LICKUSFS5621	46.07609	-114.25374	7/26/2007		0.14	0.006	0.02		
TSWQC_WQX	Lick Creek	LICKUSFS5621	46.07609	-114.25374	8/24/2007		0.06	0.007	0.02		
MDEQ_WQ_WQX	Lick Creek	C05LICKC03	46.07679	-114.25191	8/28/2012	0.5	0.06	0.04	0.018	5.9	4.26
MDEQ_WQ_WQX	Lick Creek	C05LICKC03	46.07679	-114.25191	9/28/2012	0.48	< 0.05		0.015		
MDEQ_WQ_WQX	Lick Creek	C05LICKC04	46.0775	-114.22706	8/29/2012	0.54	0.06	< 0.01	0.019	14.2	4.59
MDEQ_WQ_WQX	Lick Creek	C05LICKC04	46.0775	-114.22706	9/28/2012	0.41	< 0.05	< 0.01	0.014		
MDEQ_WQ_WQX	Lick Creek	C05LICKC20	46.09195	-114.19201	7/14/2004	E 5		< 0.01	0.038		
MTWTRSHD_WQX	Lick Creek	BTR-LICK1	46.09308	-114.19086	8/5/2010	3.83	0.11	0.02	0.03	E <50	
MDEQ_WQ_WQX	Lick Creek	C05LICKC01	46.09424	-114.18955	8/8/2012	5.54	0.13	< 0.01	0.033		
MDEQ_WQ_WQX	Lick Creek	C05LICKC01	46.09424	-114.18955	9/20/2012	2.65	< 0.05	0.04	0.022	5.3	3.60
TSWQC_WQX	Lick Creek	LICK93	46.105	-114.18538	6/26/2007		0.06	< 0.005	0.039		
TSWQC_WQX	Lick Creek	LICK93	46.105	-114.18538	7/26/2007		0.23	0.009	0.043		
TSWQC_WQX	Lick Creek	LICK93	46.105	-114.18538	8/24/2007		0.17	0.006	0.036		
MDEQ_WQ_WQX	Lick Creek	C05LICKC02	46.10497	-114.18537	8/28/2012	4.92	0.09	< 0.01	0.029		
MDEQ_WQ_WQX	Lick Creek	C05LICKC02	46.10497	-114.18537	9/28/2012	3.82	0.11	< 0.01	0.023		
MDEQ_WQ_WQX	Muddy Spring Creek	C05MUDSC02	46.38799	-113.9272	8/22/2012		0.24	0.18	0.051		
MDEQ_WQ_WQX	Muddy Spring Creek	C05MUDSC02	46.38799	-113.9272	9/29/2012	0.04	0.21	0.13	0.037		
MDEQ_WQ_WQX	Muddy Spring Creek	C05MUDSC01	46.38292	-113.9137	8/22/2012	0.22	0.24	0.19	0.048	23.4	2.44
MDEQ_WQ_WQX	Muddy Spring Creek	C05MUDSC01	46.38292	-113.9137	9/29/2012	0.26	0.27	0.16	0.04	6.4	2.68
MDEQ_WQ_WQX	North Burnt Fork Creek	C05BRFNC02	46.47118	-113.95564	8/16/2005	13.86		0.02	0.03		
MDEQ_WQ_WQX	North Burnt Fork Creek	C05BRFNC04	46.5011	-114.0091	8/29/2012	1.73	0.1	0.04	0.02		
MTWTRSHD_WQX	North Burnt Fork Creek	BTR-NBF1	46.52612	-114.08549	8/6/2010	2.37	0.21	< 0.01	0.036	26.6	22.0
MDEQ_WQ_WQX	North Burnt Fork Creek	C05BRFNC05	46.52696	-114.087	9/28/2012	4.66	0.19	< 0.01	0.021	41.4	27.0
TSWQC_WQX	North Burnt Fork Creek	BURNTWILD	46.5272	-114.08805	7/25/2006			< 0.005	0.052		
TSWQC_WQX	North Burnt Fork Creek	BURNTWILD	46.5272	-114.08805	8/2/2007		0.35	< 0.005	0.04		
TSWQC_WQX	North Burnt Fork Creek	BURNTWILD	46.5272	-114.08805	8/24/2007		0.22	< 0.005	0.029		
MDEQ_WQ_WQX	North Burnt Fork Creek	C05BRFNC01	46.54057	-114.09318	8/16/2005	0.68		< 0.01	0.056		
MDEQ_WQ_WQX	North Burnt Fork Creek	C05BRFNC01	46.54057	-114.09318	8/29/2012	E 0	0.19		0.032	<0.1	
MDEQ_WQ_WQX	North Burnt Fork Creek	C05BRFNC01	46.54057	-114.09318	9/28/2012	7.64	0.13	< 0.01	0.023		
MDEQ_WQ_WQX	North Burnt Fork Creek	C05BRFNC03	46.53987	-114.09515	8/4/2005	3.853					
TSWQC_WQX	North Burnt Fork Creek	BURNTRIVER	46.5413	-114.099	7/25/2006			< 0.005	0.065		
TSWQC_WQX	North Burnt Fork Creek	BURNTRIVER	46.5413	-114.099	8/2/2007		0.3	< 0.005	0.047		
TSWQC_WQX	North Burnt Fork Creek	BURNTRIVER	46.5413	-114.099	8/24/2007		0.19	0.007	0.037		

Table C-6. Surface Water Nutrient Data for the Bitterroot Project AreaNutrient data

Org ID	Waterbody Name	Site ID	Latitude	Longitude	Collection Date	Flow (cfs)	TN (mg/L)	TP (mg/L)	NN (mg/L)	Chlor-*a* (mg/m2)	AFDM (g/m2)
TSWQC_WQX	North Fork Rye Creek	NFRYECONF	45.97784	-114.03825	7/25/2006			0.035	0.038		
TSWQC_WQX	North Fork Rye Creek	NFRYECAT	46.02129	-114.01589	7/25/2006			0.008	0.021		
TSWQC_WQX	North Fork Rye Creek	NFRYECONF	45.97784	-114.03825	7/24/2007		0.3	0.052	0.036		
TSWQC_WQX	North Fork Rye Creek	NFRYECAT	46.02129	-114.01589	7/24/2007		0.22	< 0.005	0.022		
MDEQ_WQ_WQX	North Fork Rye Creek	C05RYNFC01	45.9973	-114.0299	8/2/2007		0.22	0.006	0.023	35.1	
TSWQC_WQX	North Fork Rye Creek	NFRYECONF	45.97784	-114.03825	8/25/2007		0.41	0.209	0.055		
TSWQC_WQX	North Fork Rye Creek	NFRYECAT	46.02129	-114.01589	8/25/2007		0.11	< 0.005	0.02		
MDEQ_WQ_WQX	North Fork Rye Creek	C05RYNFC02	45.9784	-114.03807	8/15/2012	0.37	0.33	0.16	0.035		
MDEQ_WQ_WQX	North Fork Rye Creek	C05RYNFC03	45.9945	-114.0319	8/15/2012	0.51	0.14	< 0.01	0.019	19.3	11.2
MDEQ_WQ_WQX	North Fork Rye Creek	C05RYNFC04	46.01018	-114.02368	8/15/2012	0.35	0.14	< 0.01	0.025	84.8	38.5
MDEQ_WQ_WQX	North Fork Rye Creek	C05RYNFC05	46.02445	-114.01562	8/15/2012	0.27	0.15	< 0.01	0.032		
MDEQ_WQ_WQX	North Fork Rye Creek	C05RYNFC02	45.9784	-114.03807	9/14/2012	0.5	0.17	0.06	0.022		
MDEQ_WQ_WQX	North Fork Rye Creek	C05RYNFC03	45.9945	-114.0319	9/14/2012	0.6	0.08	< 0.01	0.015		
MDEQ_WQ_WQX	North Fork Rye Creek	C05RYNFC04	46.01018	-114.02368	9/14/2012	0.45	0.09	< 0.01	0.015		
MDEQ_WQ_WQX	North Fork Rye Creek	C05RYNFC05	46.02445	-114.01562	9/14/2012	0.34	0.09	0.04	0.016		
MTWTRSHD_WQX	Rye Creek	BTR-RYE4	45.9762	-114.04179	8/3/2010		0.19	< 0.01	0.048	20.6	28.7
MDEQ_WQ_WQX	Rye Creek	C05RYEC02	45.97528	-114.06193	8/9/2012	0.89	0.15	< 0.01	0.027		
MDEQ_WQ_WQX	Rye Creek	C05RYEC02	45.97528	-114.06193	9/13/2012	1.14	0.13	< 0.01	0.022		
MTWTRSHD_WQX	Rye Creek	BITR-C05RYEC02	45.96634	-114.135	8/2/2010	3.4	0.19	0.04	0.023	35.6	15.1
MDEQ_WQ_WQX	Rye Creek	C05RYEC01	45.9672	-114.1355	8/7/2012	1.25	0.17	< 0.01	0.01		
MDEQ_WQ_WQX	Rye Creek	C05RYEC01	45.9672	-114.1355	9/13/2012	1.91	0.1		0.006		
TSWQC_WQX	Rye Creek	RYEBEL93	45.96689	-114.13551	7/25/2006			0.011	0.019		
TSWQC_WQX	Rye Creek	RYEBEL93	45.96689	-114.13551	7/24/2007		0.28	0.02	0.043		
TSWQC_WQX	Rye Creek	RYEBEL93	45.96689	-114.13551	8/25/2007		0.37	0.084	0.051		
MDEQ_WQ_WQX	Sweathouse Creek	C05SWTHC02	46.4213	-114.2462	9/17/2007		0.104		0.0091		
MDEQ_WQ_WQX	Sweathouse Creek	C05SWTHC02	46.4213	-114.2462	8/21/2008		0.23		0.017		
MDEQ_WQ_WQX	Sweathouse Creek	C05SWTHC02	46.4213	-114.2462	9/20/2008		0.18		0.001		
MDEQ_WQ_WQX	Sweathouse Creek	C05SWTHC05	46.41703	-114.22763	8/23/2012	3.95	0.09	0.07	< 0.005		
MDEQ_WQ_WQX	Sweathouse Creek	C05SWTHC04	46.412	-114.19724	8/15/2012	5.67	0.09	< 0.01	0.008		
MDEQ_WQ_WQX	Sweathouse Creek	C05SWTHC04	46.412	-114.19724	9/19/2012	1.66	< 0.05	0.03	0.01	13.2	4.55
MTWTRSHD_WQX	Sweathouse Creek	BTR-SWEAT2	46.41214	-114.19697	8/5/2010	5.11	0.11	0.05	0.01	E <50	
TSWQC_WQX	Sweathouse Creek	SWEATREDCR	46.41206	-114.19692	7/24/2006			0.006	0.013		
TSWQC_WQX	Sweathouse Creek	SWEATREDCR	46.41206	-114.19692	7/25/2007		0.17	0.028	0.011		
TSWQC_WQX	Sweathouse Creek	SWEATREDCR	46.41206	-114.19692	8/24/2007		0.048	0.01	0.006		
MDEQ_WQ_WQX	Sweathouse Creek	C05SWTHC03	46.4238	-114.1462	8/14/2012	2.09	0.23	< 0.01	0.042		
MDEQ_WQ_WQX	Sweathouse Creek	C05SWTHC03	46.4238	-114.1462	9/19/2012	2.34	0.12	0.03	0.034		
TSWQC_WQX	Sweathouse Creek	SWEATMOU	46.42572	-114.13744	7/24/2006			0.016	0.057		
TSWQC_WQX	Sweathouse Creek	SWEATMOU	46.42572	-114.13744	7/25/2007		0.5	0.018	0.058		
TSWQC_WQX	Sweathouse Creek	SWEATMOU	46.42572	-114.13744	8/24/2007		0.25	0.022	0.053		
MTWTRSHD_WQX	Sweathouse Creek	BTR-SWEAT1	46.42569	-114.13607	8/5/2010	2.11	0.31	0.04	0.049	16.7	5.38
TSWQC_WQX	Threemile Creek	THMFWP-6	46.62185	-113.89895	7/24/2006			0.027	0.044		
TSWQC_WQX	Threemile Creek	THMFWP-6	46.62185	-113.89895	8/1/2007		0.15	0.018	0.041		
TSWQC_WQX	Threemile Creek	THMFWP-6	46.62185	-113.89895	8/27/2007		0.076	0.019	0.041		
MTWTRSHD_WQX	Threemile Creek	BTR-THREEMILE4	46.62352	-113.90874	8/7/2010	2.12	< 0.05	0.02	0.044	E <50	
TSWQC_WQX	Threemile Creek	THMTMRD-3	46.57843	-113.97235	7/31/2003				0.111		
MTWTRSHD_WQX	Threemile Creek	BTR-THREEMILE3	46.57555	-113.9829	8/7/2010	7.46	0.51	0.29	0.076	7.5	3.22
MTWTRSHD_WQX	Threemile Creek	BTR-THREEMILE2	46.57062	-114.02635	8/6/2010	7.02	0.78	0.48	0.12	E <50	
TSWQC_WQX	Threemile Creek	THMCONFL-2	46.56463	-114.03713	7/31/2003			0.42	0.143		

Table C-6. Surface Water Nutrient Data for the Bitterroot Project AreaNutrient data

Org ID	Waterbody Name	Site ID	Latitude	Longitude	Collection Date	Flow (cfs)	TN (mg/L)	TP (mg/L)	NN (mg/L)	Chlor-*a* (mg/m2)	AFDM (g/m2)
TSWQC_WQX	Threemile Creek	THMCONFL-2	46.56463	-114.03713	7/24/2006			0.837	0.144		
TSWQC_WQX	Threemile Creek	THMCONFL-2	46.56463	-114.03713	8/2/2007		1.2	0.509	0.14		
TSWQC_WQX	Threemile Creek	THMCONFL-2	46.56463	-114.03713	8/27/2007		0.71	0.441	0.104		

E = Estimated

A "<" symbol indicates a non-detect sample. The detection limit is entered after the "<" symbol.

APPENDIX D - CLEANUP/RESTORATION AND FUNDING OPTIONS FOR MINE OPERATIONS OR OTHER SOURCES OF METALS CONTAMINATION

There are several approaches for cleanup of mining operations or other sources of metals contamination in the state of Montana. Most of these are discussed below, with focus on abandoned or closed mining operations.

D1.0 THE COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA)

CERCLA is a federal law that addresses cleanup on sites, such as historic mining areas, where there has been a hazardous substance release or threat of release. Sites are prioritized on the National Priority List (NPL) using a hazard ranking system with significant focus on human health. Petroleum related products and associated raw materials are not covered under CERCLA. Other federal regulations such as Resource Conservation and Recovery Act and associated Leaking Underground Storage Tank cleanup requirements tend to address petroleum.

Under CERCLA, the potentially responsible party or parties must pay for all remediation efforts based upon the application of a strict joint and several liability approach whereby any existing or historical land owner can be held liable for restoration costs. Where viable landowners are not available to fund cleanup, funding can be provided under Superfund authority. Federal agencies can be delegated Superfund authority, but cannot access funding from Superfund.

Cleanup actions under CERCLA must be based on professionally developed plans and can be categorized as either Removal or Remedial. Removal actions can be used to address the immediate need to stabilize or remove a threat where an emergency exists. Cleanup of metals-contaminated soils in the Town of Superior was performed as a removal action.

Once removal activities are completed, a site can then undergo Remedial Actions or may end up being scored low enough from a risk perspective that it no longer qualifies to be on the NPL for Remedial Action. Under these conditions the site is released back to the state for a "no further action" determination. At this point there may still be a need for additional cleanup since there may still be significant environmental threats or impacts, although the threats or impacts are not significant enough to justify Remedial Action under CERCLA. Any remaining threats or impacts would tend to be associated with wildlife, aquatic life, or aesthetic impacts to the environment or aesthetic impacts to drinking water supplies versus threats or impacts to human health. A site could, therefore, still be a concern from a water quality restoration perspective, even after CERCLA removal activities have been completed.

Remedial actions may or may not be associated with or subsequent to removal activities. A remedial action involves cleanup efforts whereby Applicable or Relevant and Appropriate Requirements and Standards (ARARS), which include state water quality standards, are satisfied. Once ARARS are satisfied, then a site can receive a "no further action" determination.

D2.0 The Montana Comprehensive Cleanup and Restoration Act (CECRA)

The 1985 Montana Legislature passed the Environmental Quality Protection Fund Act. This Act created a legal mechanism for the Department to investigate and clean up, or require liable persons to investigate and clean up, hazardous or deleterious substance facilities in Montana. The 1985 Act also established the Environmental Quality Protection Fund (EQPF). The EQPF is a revolving fund in which all penalties and costs recovered pursuant to the EQPF Act are deposited. The EQPF can be used only to fund activities relating to the release of a hazardous or deleterious substance. Although the 1985 Act established the EQPF, it did not provide a funding mechanism for the Department to administer the Act. Therefore, no activities were conducted under this Act until 1987.

The 1989 Montana Legislature significantly amended the Act, changing its name to the Montana Comprehensive Environmental Cleanup and Responsibility Act (CECRA) and providing the Department with similar authorities as provided under the federal Superfund Act (CERCLA). With the passage of CECRA, the state Superfund program became the CECRA Program. Major revisions to CECRA did not occur until the 1995 Legislature, when the Voluntary Cleanup and Redevelopment Act (VCRA), a mixed-funding pilot program, and a requirement to conduct a collaborative study on alternative liability schemes were added and provisions related to remedy selection were changed. Based on the results of the collaborative study, the 1997 Legislature adopted the Controlled Allocation of Liability Act, which provides a voluntary process for the apportionment of liability at CECRA facilities and establishes an orphan share fund. Minor revisions to CECRA were also made by the 1999 and 2001 Legislatures.

CECRA facilities are ranked maximum, high, medium, low and operation and maintenance priority based on the severity of contamination at the facility and the actual and potential impacts of contamination to public health, safety, and welfare and the environment. The Department maintains database narratives that explain contamination problems and status of work at each state Superfund facility.

D2.1 The Controlled Allocation of Liability Act (CALA)

The Montana Legislature added the Controlled Allocation of Liability Act (CALA; §§ 75-10-742 through 752, Montana Code Annotated (MCA)) to the Comprehensive Environmental Cleanup and Responsibility Act (CECRA; §§ 75-10-701 through 752, MCA), the state Superfund law, in 1997. The department administers CALA including the orphan share fund it establishes.

CALA is a voluntary process that allows Potentially Responsible Parties (PRP) to petition for an allocation of liability as an alternative to the strict, joint and several liability scheme included in CECRA. CALA provides a streamlined alternative to litigation that involves negotiations designed to allocate liability among persons involved at facilities requiring cleanup, including bankrupt or defunct persons. Cleanup of these facilities must occur concurrently with the CALA process and CALA provides the funding for the orphan share of the cleanup. Since CECRA cleanups typically involve historical contamination, liable persons often include entities that are bankrupt or defunct and not affiliated with any viable person by stock ownership. The share of cleanup costs for which these bankrupt or defunct persons are responsible is the orphan share. Department represents the interests of the orphan share throughout the CALA process.

The funding source known as the orphan share fund is a state special revenue fund created from a variety of sources. These include an allocation of 8.5 percent of the metal mines license tax, certain penalties and additional funds from the resource indemnity trust fund and 25 percent of the resource indemnity and groundwater assessment taxes (which will increase to 50 percent when the reach indexing tool reaches $100 million). The current balance of the Orphan Share Fund is around $4 million and revenues projected for the rest of this biennium are about $2 million.

In the absence of a demonstrated hardship, claims for orphan share reimbursement may not be submitted until the cleanup is complete. This ensures that facilities are fully remediated before reimbursement. The result is that a PRP could be expending costs it anticipates being reimbursed for some time before the PRP actually submits a claim.

CALA was designed to be a streamlined, voluntary allocation process. For facilities where a PRP does not initiate the CALA process, strict, joint and several liability remains. Any person who has been noticed as being potentially liable as well as any potentially liable person who has received approval of a voluntary cleanup plan can petition to initiate the CALA process. CALA includes fourteen factors to be considered in allocating liability. Based on these factors causation weighs heavily in allocation but is not the only factor considered.

D2.2 The Voluntary Cleanup and Redevelopment Act (VCRA)

The 1995 Montana Legislature amended the Comprehensive Environmental Cleanup and Responsibility Act (CECRA), creating the Voluntary Cleanup and Redevelopment Act (VCRA) (Sections 75-10-730 through 738, MCA). VCRA formalizes the voluntary cleanup process in the state. It specifies application requirements, voluntary cleanup plan requirements, agency review criteria and time frames, and conditions for and contents of no further action letters.

The act was developed to permit and encourage voluntary cleanup of facilities where releases or threatened releases of hazardous or deleterious substances exist, by providing interested persons with a method of determining what the cleanup responsibilities will be for reuse or redevelopment of existing facilities. Any entity (such as facility owners, operators, or prospective purchasers) may submit an application for approval of a voluntary cleanup plan to the Department. Voluntary Cleanup Plans (VCPs) may be submitted for facilities whether or not they are on the CECRA Priority List. The plan must include (1) an environmental assessment of the facility; (2) a remediation proposal; and (3) the written consent of current owners of the facility or property to both the implementation of the voluntary cleanup plan and access to the facility by the applicant and its agents and Department. The applicant is also required to reimburse the Department for any costs that the state incurs during the review and oversight of a voluntary cleanup effort.

The act offers several incentives to parties voluntarily performing facility cleanup. Any entity can apply and liability protection is provided to entities that would otherwise not be responsible for site cleanup. Cleanup can occur on an entire facility or a portion of a facility. The Department cannot take enforcement action against any party conducting an approved voluntary cleanup. The Department review process is streamlined: the Department has 30 to 60 days to determine if a voluntary cleanup plan is complete, depending on how long the cleanup will take. When the Department determines an application is complete, it must decide within 60 days whether to approve or disapprove of the application; these 60 days also includes a 30-day public comment period. The Department's decision is based on the proposed uses of the facility identified by the applicant and the applicant conducts any necessary risk evaluation. Once a plan has been successfully implemented and Department costs have been paid, the applicant can petition the Department for closure. The Department must determine whether closure conditions are met within 60 days of this petition and, if so, the Department will issue a closure letter for the facility or the portion of the facility addressed by the voluntary cleanup.

The act is contained in §§ 75-10-730 through 738, MCA. Major sections include: § 75-10-732 - eligibility requirements; § 75-10-733 and § 75-10-734 - environmental property assessment and remediation proposal requirements; § 75-10-735 - public participation; § 75-10-736 - timeframes and procedures for Department approval/disapproval; § 75-10-737 - voluntary action to preclude remedial action by Department of Environmental Quality (DEQ); and § 75-10-738 - closure process. Section 75-10-721, MCA of CECRA must also be met.

The Department does not currently have a memorandum of agreement (MOA) with the Environmental Protection Agency (EPA) for its Voluntary Cleanup Program. However, the Department and EPA are in the process of negotiating one. EPA has indicated that Montana's Voluntary Cleanup Program includes the necessary elements to establish the MOA. Currently, EPA is reviewing the latest draft of the MOA.

The Department has produced a VCRA Application Guide to assist applicants in preparing a new application; this guide is not a regulation and adherence to it is not mandatory.

As of 2012, the Department has approved 31 voluntary clean plans, including mining, manufactured gas, wood treating, dry cleaning, salvage, pesticide, fueling, refining, metal plating, defense, and automotive repair facilities. Applicants have expressed interest and/or submitted applications for voluntary cleanup at fifteen other facilities. The Department maintains a registry of VCRA facilities.

D3.0 Abandoned Mine Lands Cleanup

The purpose of the Abandoned Mine Lands Reclamation (AML) Program is to protect human health and the environment from the effects of past mining and mineral processing activities. Funding for cleanup is via the Federal Abandoned Mine Fund, which is distributed to the State of Montana via a grant program. The Abandoned Mine Fund is generated by a per ton fee levied on coal producers and the annual grant it based on coal production. There are no collections or contributions to the Abandoned Mine Fund from mineral production beyond coal production fees. Expenditures under the abandoned mine program can only be made on “eligible” abandoned mine sites. For a site to be eligible, mining must have ceased prior to August 4, 1977 (private lands, other dates apply to federal lands). In addition, there must be no continuing reclamation responsibility under any state or federal law. No continuing reclamation responsibility can mean no mining bonds or permits have been issued for the site, however, it has also been interpreted to mean that there can be no viable responsible party under State or Federal laws such as CERCLA or CECRA. While lands eligible for the Abandoned Mine Funds include hard rock mines and gravel pits (collectively categorized as “non-coal”), abandoned coalmines have the highest priority for expenditures from the Fund. As part of the approved plan for Montana, abandoned coal mines are required to be prioritized and funded for reclamation ahead of eligible non-coal mine sites. . Cleanup of any eligible site is prioritized based primarily on human health, which can include health risks such as open shafts, versus risks only associated with hazardous substances, as is the case under CERCLA.

Montana's AML Program maintains an inventory of all potential cleanup sites, and also has a list of non-coal priority sites from which to work from. The DEQ conducts cleanups under the Abandoned Mine

Funds as public works contracts utilizing professional engineers for design purposes and private construction contractors to perform the actual work.

Limited scoping and ranking of water pollution from discharging abandoned coal mines has been completed and Montana's AML program is evaluating how to proceed with funding water treatment and stream quality restoration at the highest priority abandoned coal mine sites. In cases of non-coal cleanups, mitigating impacts associated with discharging adits can be included within the cleanup, although ongoing water treatment is not pursued as a reclamation option to avoid long-term operational commitments, which are outside the scope of the program and funding source. Therefore, even after cleanup, an abandoned non-coal mine site could still represent a source of contaminant loading to a stream, especially if there is a discharging adit associated with the site. Where discharging adits are not of concern, cleanup of either coal or non-coal mines may generally represent efforts to achieve all reasonable land, water, and soil conservation practices for that site.

A Guide to Abandoned Mine Reclamation (Noble and Koerth, 1996) provides further description of the Abandoned Mine Lands Program and how cleanup activities are pursued.

D4.0 Cleanup on Federal Agency Lands

A Federal land management agency may pursue cleanup actions outside of any requirements under CERCLA or CECRA where such activities are consistent with overall land management goals and funding availability. This is the anticipated solutions for United States Forest Service (USFS) lands within the Flat Creek watershed.

D5.0 Permitted or Bonded Sites

Newer mining sites that are or have been in recent operation are required to post bonds as part of their permit conditions. These bond and permit conditions help ensure cleanup to levels that will satisfy Montana Water Quality Standards during operation and after completion of a mining operation. Such sites also include larger placer mines greater than 5 acres in size.

D6.0 Voluntary Cleanup Agreement

At least one location within Montana (the Upper Blackfoot Mining Complex) is being addressed via a voluntary cleanup approach based on an agreement between the responsible person and the State of Montana. Although similar in nature to the goals of CECRA, this cleanup effort is currently not considered a remedial action under CECRA. The responsible person is responsible for cleanup costs in this situation.

D7.0 Landowner Voluntary Cleanup Outside of a State Directed or State Negotiated Effort

A landowner could pursue cleanup outside the context of CECRA or other state negotiated cleanup approaches. Under such conditions, liability would still exist since there is presumably a lack of professional oversight and assurance of meeting appropriate environmental and human health goals. Regulatory requirements such as where waste can be disposed, stormwater runoff protection, and multiple other environmental conditions would still need to be followed to help ensure that the cleanup activity does not create new problems. This approach can be risky since the potential for additional future work would likely make it more cost effective to pursue cleanup under CECRA or some other state negotiated approach where PRP liability can be resolved.

D8.0 State Emergency Actions

Where a major emergency exists, the State can undertake remedial actions and then pursue reimbursement from a responsible party. This situation does not exist within the Bitterroot Watershed Project Area.

D9.0 References

Noble, Cassandra and John Koerth. 1996. Montana ... Bringing the Land Back to Life: A Guide to Abandoned Mine Reclamation. Helena, MT: Montana Department of Environmental Quality.

ATTACHMENT A - MODELING WATER TEMPERATURE IN MILL CREEK

Modeling Water Temperature in Mill Creek

Prepared for:

U.S. Environmental Protection Agency, Region 8
Montana Operations Office
10 West 15th Street, Suite 3200
Helena, MT 59626

Prepared by:

Tetra Tech, Inc.
P.O. Box 11895
Jackson, WY 83002

June 23, 2014

Version

Report date	Version number	Description
6/2/2014	1.0	First full draft to agencies for initial review
6/18/2014	1.1	DEQ project manager & U.S. EPA Region 8 comments
6/18/2014	1.2	DEQ modeler comments
6/23/2014	2.0	DEQ & EPA comments addressed; final report

Contents

Tables

Figures

Acronyms and Abbreviations

AME	absolute mean error
EPA	U.S. Environmental Protection Agency
DEQ	Montana Department of Environmental Quality
MPDES	Montana Pollutant Discharge Elimination System
QUAL2K	River and Stream Water Quality Model
REL	relative error
TMDL	total maximum daily load
USGS	U.S. Geological Survey (U.S. Department of the Interior)

Units of Measure

°F	degrees Fahrenheit
cfs	cubic feet per second
cm^2/s	square centimeter per second
g/cm^3	grams per cubic centimeter
MSL	mean sea level
RM	river mile

Executive Summary

Mill Creek was identified by the Montana Department of Environmental Quality (DEQ) as being impaired due to elevated water temperatures. The cause of the impairment was attributed to loss of riparian habitat and site clearance (land development or redevelopment) (DEQ 2013). The U.S. Environmental Protection Agency (EPA) contracted with Tetra Tech to develop a QUAL2K water quality model to investigate the relationship between flow, shade, and in-stream water temperature.

Field studies were carried out in 2013 to support water quality model development for the project. A QUAL2K water-quality model was then developed for Mill Creek to evaluate management practices suitable for meeting state temperature standards. The QUAL2K model was constructed, in part, using field-collected data from the summer of 2013. Shade v3.0 models were also developed to assess shade conditions using previously collected field data. The calibrated and validated QUAL2K model met previously designated acceptance criteria. Once developed, various water temperature responses were evaluated for a range of potential watershed management activities. Four scenarios were considered:

- **Scenario 1:** Baseline condition (i.e., synthetic flow and weather conditions to represent August).
- **Scenario 2:** Baseline with a 15 percent reduction of water withdrawals.
- **Scenario 3:** Baseline with improved riparian vegetation in certain segments based upon reference segments.
- **Scenario 4:** An improved flow and shade scenario that combines the potential benefits associated with a 15 percent reduction in water withdrawals with improved shading along certain segments.

In comparison to scenario 1, results ranged from minimal change in water temperature (scenario 3) to considerable reductions (scenarios 2 and 4). The improved flow and shade scenario (scenario 4), which combined the potential benefits associated with a 15 percent reduction in water withdrawals (scenario 2) with improved shading to certain segments based upon reference segments (scenario 3) to represent application of conservation practices, resulted in overall reductions along the entire reach that ranged from no effect to 10° F. Generally, small changes in shade or inflow had minimal effects on water temperature while large increases in shade or decreases in irrigation withdrawals had a considerable effect on water temperature.

1 Introduction

Tetra Tech, Inc. is under contract with the U.S. Environmental Protection Agency (EPA) to set up, calibrate, validate, and conduct scenario analysis with a temperature model (QUAL2K) for Mill Creek in support of total maximum daily load (TMDL) development by the Montana Department of Environmental Quality (DEQ). Background information is provided in the following section (**Section 2**). A summary of model set up and calibration is provided in **Section 3** and a series of model scenarios and results are presented in **Section 4**.

2 Background

This section presents background information to support QUAL2K model development.

2.1 Problem Statement

Mill Creek is in western Montana and is part of the Bitterroot TMDL Planning Area. The Mill Creek watershed is in the Bitterroot 8-digit HUC (17010205). The impaired segment is 8.72 miles long and extends from the Selway-Bitterroot boundary to the mouth on Fred Burr Creek (DEQ 2013) (**Figure 1**).

Mill Creek has a B-1 use class. The impaired segment is not supporting its Aquatic Life and Primary Contact Recreation designated uses (DEQ 2013). Three potential causes of impairment are identified in the assessment record, including water temperature (DEQ-2013). The potential sources of the water temperature impairment are: loss of riparian habitat and site clearance (land development or redevelopment) (DEQ 2013).

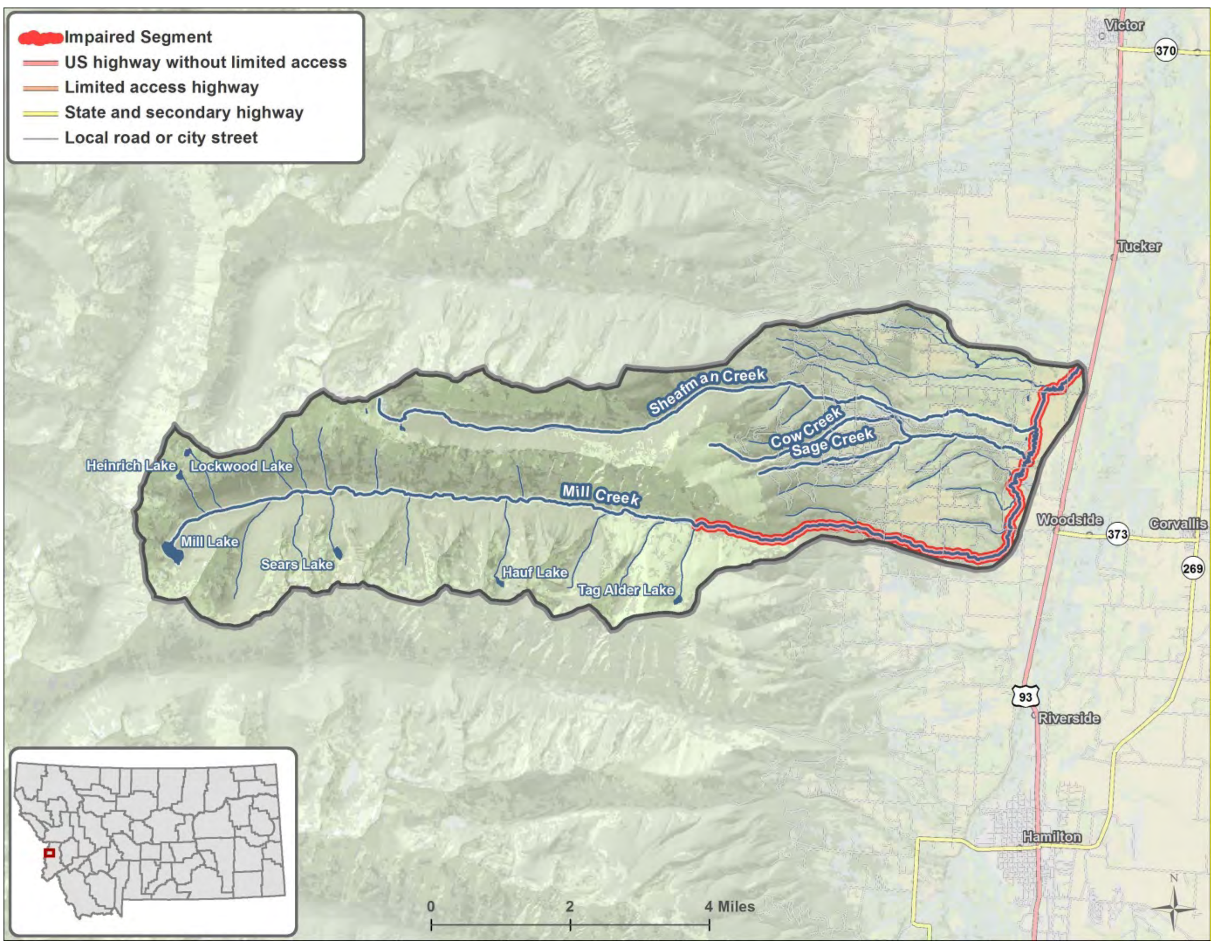


Figure 1. Mill Creek watershed.

2.2 Montana Temperature Standard

For a waterbody with a use classification of B-1, the following temperature criteria apply:[1]

> A 1° F maximum increase above naturally occurring water temperature is allowed within the range of 32° F to 66° F; within the naturally occurring[2] range of 66° F to 66.5° F, no discharge is allowed [that] will cause the water temperature to exceed 67° F; and where the naturally occurring water temperature is 66.5° F or greater, the maximum allowable increase in water temperature is 0.5° F. A 2° F per-hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55° F. A 2° F maximum decrease below naturally occurring water temperature is allowed within the range of 55° F to 32° F.

The model results will ultimately be compared to these criteria.

2.3 Project History

Tetra Tech was contracted by EPA in May 2013 to develop the QUAL2K temperature model using the data and information that was collected in the summer of 2013. Temperature and flow data were collected in Mill Creek in 2013 by Tetra Tech. A field team from Tetra Tech collected data on July 26-27, 2013, August 12-13, 2013, September 9, 2013 and September 12, 2013 to characterize flow and shade in support of the modeling effort.

2.4 Factors Potentially Influencing Stream Temperature

Stream temperature regimes are influenced by processes that are external to the stream as well as processes that occur within the stream and its associated riparian zone (Poole et al. 2001). Examples of factors external to the stream that can affect in-stream water temperatures include: topographic shade, land use/land cover (e.g., vegetation and the shading it provides, impervious surfaces), solar angle, meteorological conditions (e.g., precipitation, air temperature, cloud cover, relative humidity), groundwater exchange and temperature, irrigation return flows, and tributary inflow temperatures and volumes. The shape of the channel can also affect temperature—wide shallow channels are more easily heated and cooled than deep, narrow channels. The amount of water in the stream is another factor influencing stream temperature regimes. Streams that carry large amounts of water resist heating and cooling, whereas temperature in small streams (or reduced flows) can be changed more easily.

The following factors that may have an influence on stream temperatures in Mill Creek were evaluated prior to model development and are further discussed in **Appendix A**:

- Local/regional climate
- Land ownership
- Land use
- Riparian vegetation
- Shade
- Hydrology

[1] ARM 17.30.623(e).

[2] "Naturally occurring" means conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil and water conservation practices have been applied.

- Point sources

2.5 Observed Stream Temperatures

Tetra Tech collected stream temperature data using in-stream loggers at multiple locations in the Mill Creek watershed. These data are presented and summarized in the following sections.

2.5.1 Available Temperature Data

In 2013, Tetra Tech collected continuous temperature data at six sites along Mill Creek and at one tributary site (Sheafman Creek) in support of this modeling effort (**Figure 2**). Data loggers recorded temperatures every one-half hour for two months between June 26-27 and September 9, 2013. In 2007, Montana DEQ collected continuous temperature data at two locations on Mill Creek (sites C05MILLC01 and C05MILLC02). Tetra Tech also collected instantaneous temperatures from Mill Creek (**Appendix A**). Temperatures varied spatially and temporally; generally, the warmest instantaneous temperatures were detected in July. Additionally, Montana DEQ recorded an instantaneous temperature of 76.5° F on July 12, 2007, at the C05MILLC01 station.

Tetra Tech identified a period of time at the logger on Sheafman Creek (SC-TT1) when the logger was likely exposed to ambient air: July 13 through September 12, 2013. These data were excluded from analyses and model development.

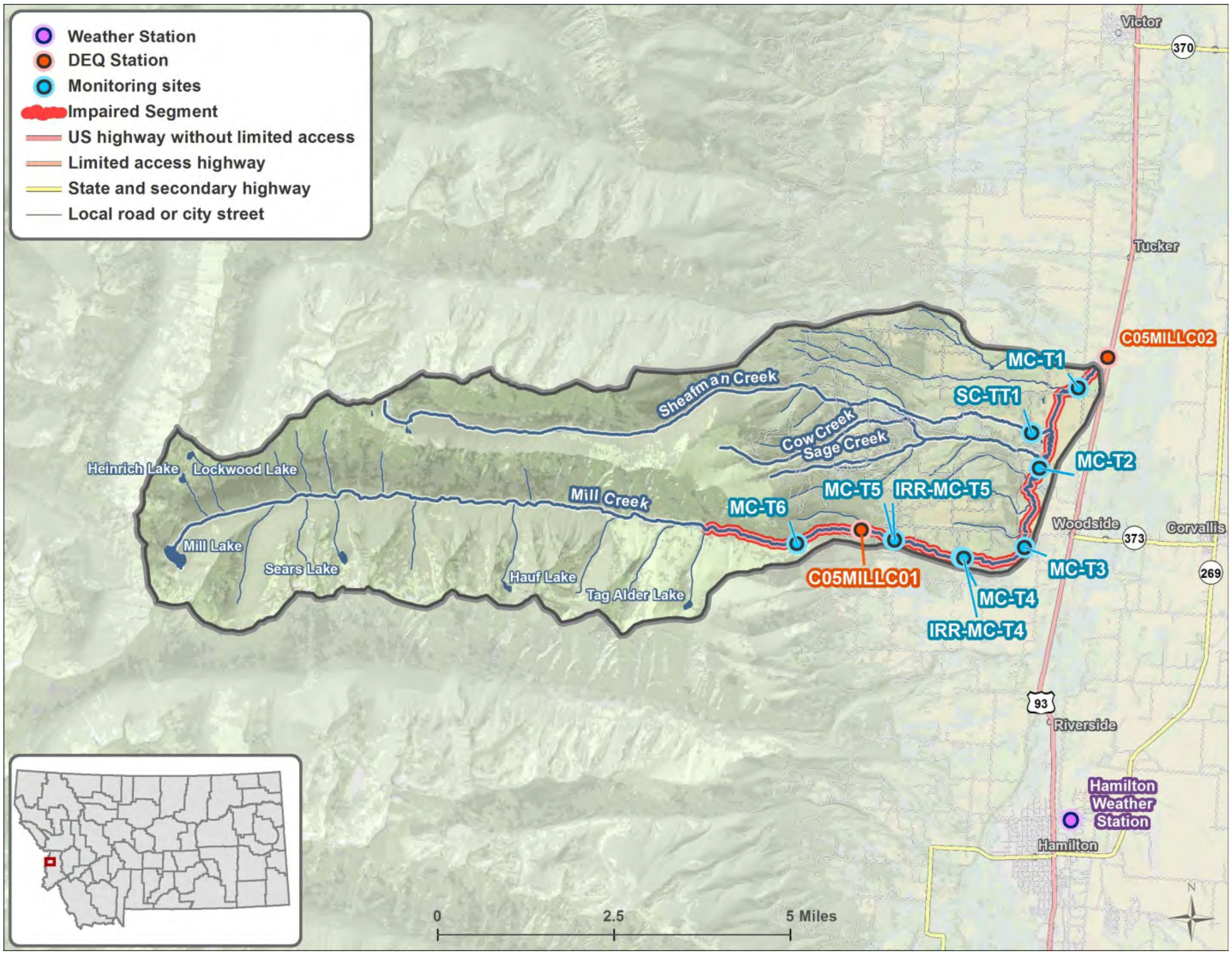
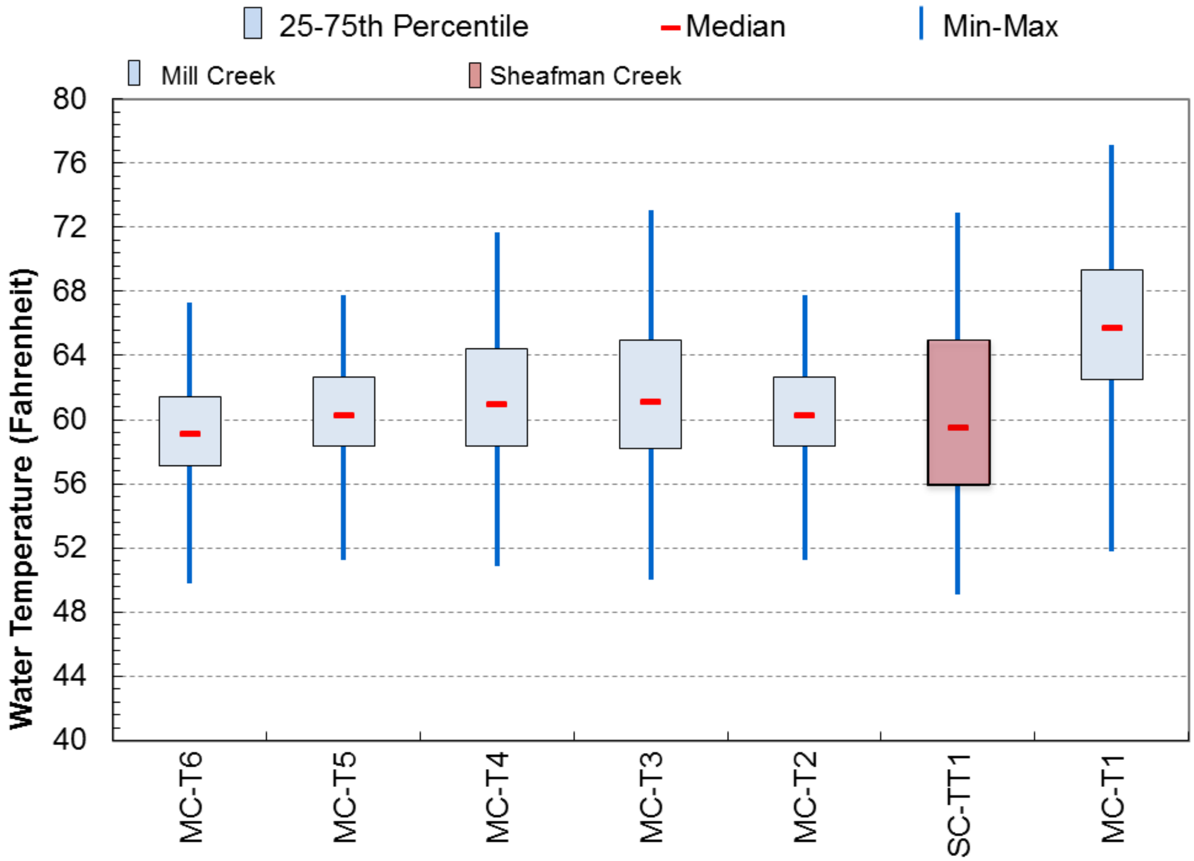


Figure 2. Temperature loggers in the Mill Creek watershed.

2.5.2 Temperature Data Analysis

Stream temperatures in Mill Creek generally increase from its source downstream to its mouth. A summary of the continuous temperature data collected by Tetra Tech is provided in (**Figure 3**)**.** Median temperatures in Mill Creek ranged from approximately 59° F to approximately 66° F in 2013 (**Figure 3**) and from approximately 55.4° F to approximately 57.2° F in 2007.



Note: Logger SC-TT1 may have been exposed to ambient air from July 13, 2013 through September 12, 2013. The data presented in this figure are limited to a subset of the monitored temperatures from June 27, 2013 through July 12, 2013.

Figure 3. Box-and-whisker plots of summer 2013 Tetra Tech continuous temperature data.

Maximum daily temperatures in Mill Creek ranged from approximately 67.3° F to 77.1° F in July of 2013 (**Table 1** and **Figure 4**). The highest maximum temperatures were recorded near the mouth at MC-T1. In 2013, the warmest temperatures were detected on July 18 and July 23-26. Similarly, in 2007, the maximum daily temperatures at sites C05MILLC01 and C05MILLC02 were 68.4° and 70.9° F (respectively) and occurred on July 18 (**Table 2** and **Figure 5**). The warmest weeks were generally the third and fourth weeks of July. As shown in **Figure 6**, the diurnal variation in Mill Creek in the upper watershed (as shown with MC-T6) is often only two-thirds of the diurnal variation in the lower watershed (as shown with MC-T1).

Table 1. Maximum and maximum weekly maximum temperatures in Mill Creek, 2013

Temperature logger site	Maximum temperatures [a]		Maximum weekly maximum temperature [b]	
	Temperature (°F)	Date	Temperature (°F)	Date
MC-6 (upper segment)	67.3	July 23	66.6	July 20-26
MC-5	67.8	July 24	67.3	July 20-26
MC-4	71.7	July 26	71.2	July 20-26
MC-3	73.0	July 18	72.2	July 17-23
MC-2	70.0	July 18	68.6	July 15-21
MC-1 (mouth)	77.1	July 18	76.4	July 18-24

Notes

a. Maximum temperature is the maximum of recorded one-half hourly temperatures.

b. Maximum weekly maximum temperature is the mean of daily maximum water temperatures measured over the warmest consecutive seven-day period.

Table 2. Maximum and maximum weekly maximum temperatures in Mill Creek, 2007

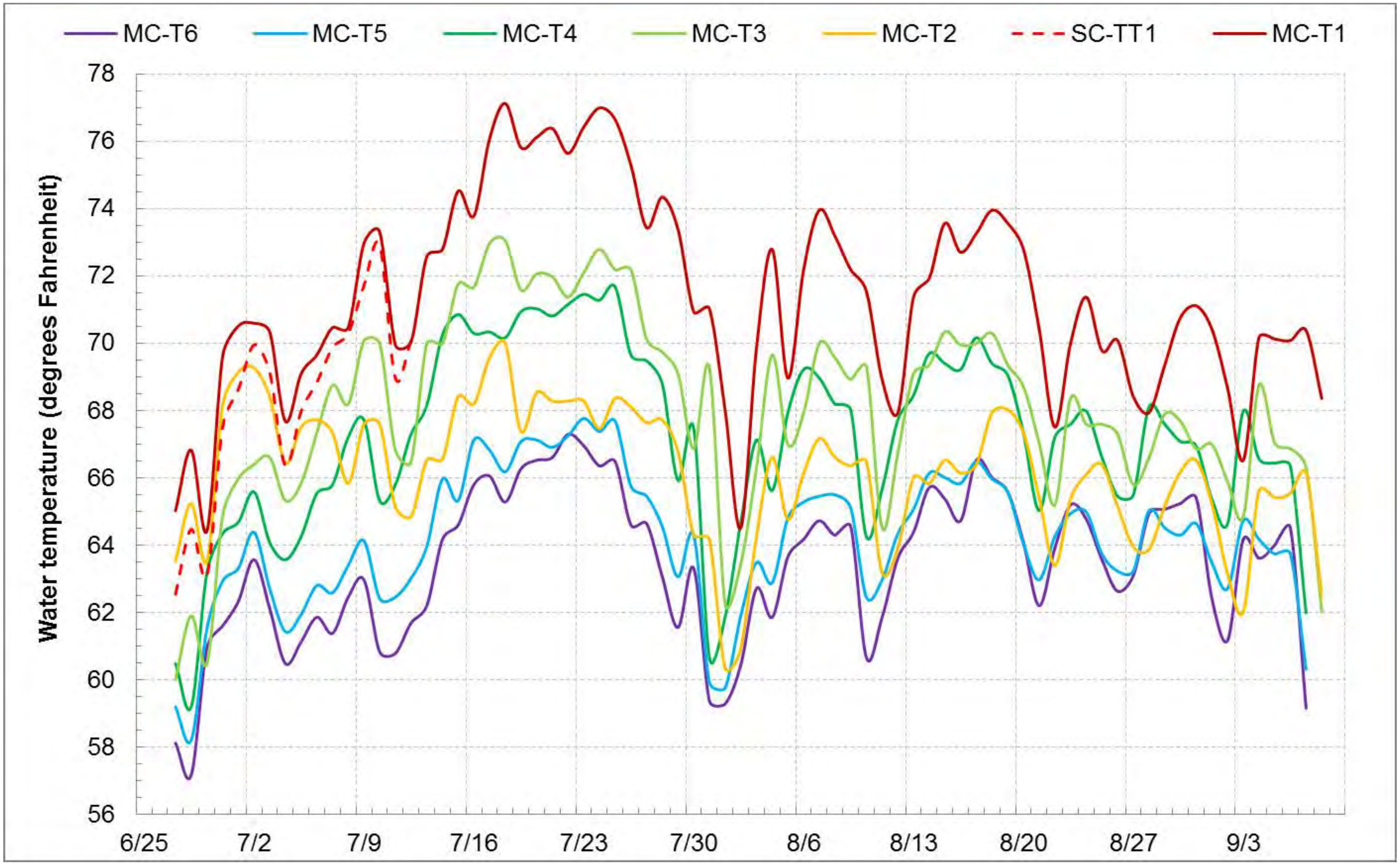
Temperature logger site	Maximum temperatures [a]		Maximum weekly maximum temperature [b]	
	Temperature (°F)	Date	Temperature (°F)	Date
C05MILLC01	68.4	July 18	67.6	July 14-20
C05MILLC02	70.9	July 18	69.5	July 16-22

Notes

Only data from July 13, 2007 through August 9, 2007 were used to assess the maximum and maximum weekly maximum temperatures.

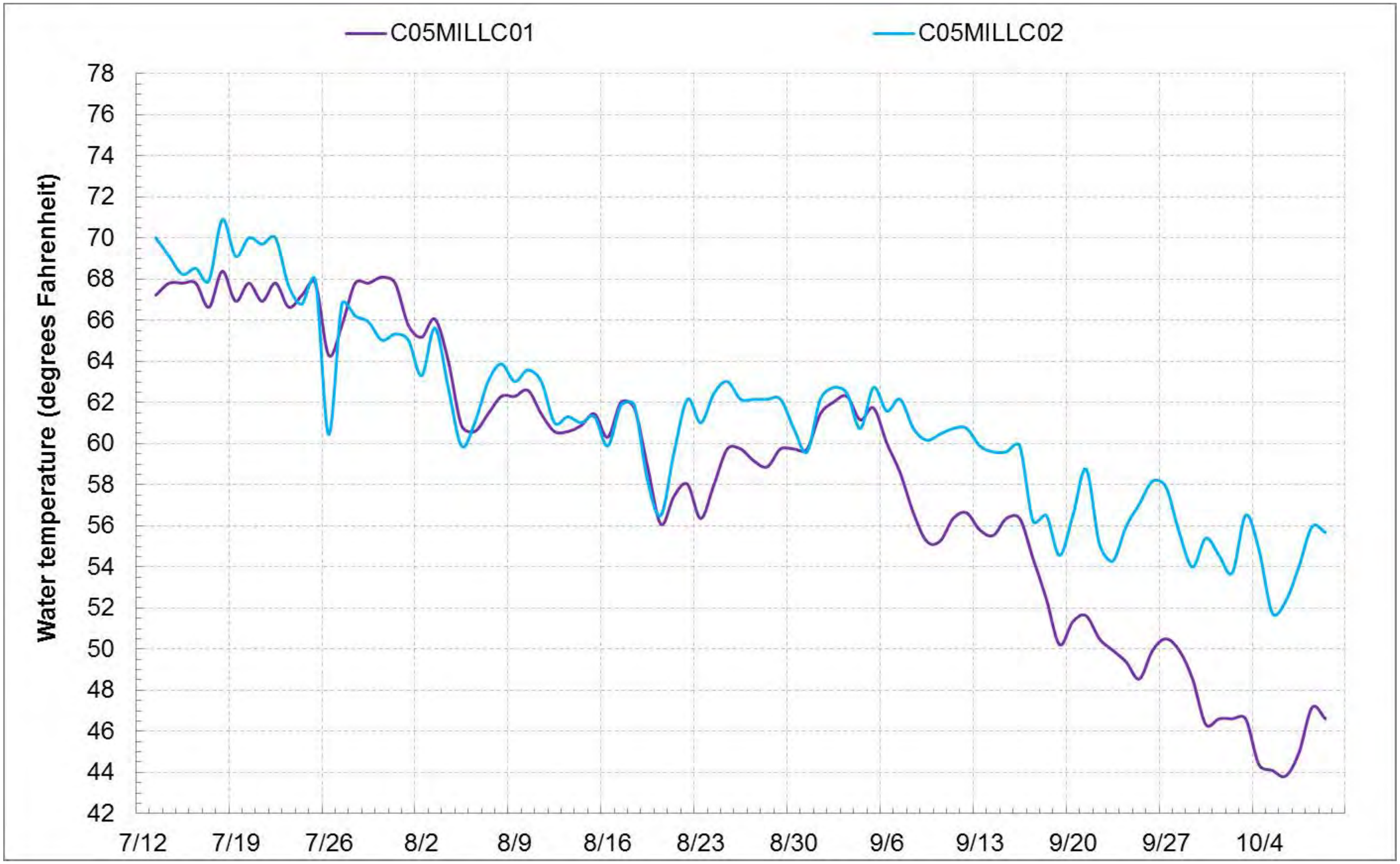
a. Maximum temperature is the maximum of recorded one-half hourly temperatures.

b. Maximum weekly maximum temperature is the mean of daily maximum water temperatures measured over the warmest consecutive seven-day period.



Note: Logger SC-TT1 may have been exposed to ambient air from July 13, 2013 through September 12, 2013. The data presented in this figure are limited to a subset of the monitored temperatures from June 27, 2013 through July 12, 2013.

Figure 4. Daily maximum temperatures, Mill Creek and a tributary (dashed line), June 26-27 to September 9, 2013.



Note: Data from both loggers from July 11-12, 2007 and October 10-25, 2007 were excluded. Data from these time periods were significantly warmer than from July 13, 2007 - October 9, 2007.

Figure 5. Daily maximum temperatures in Mill Creek (2007).

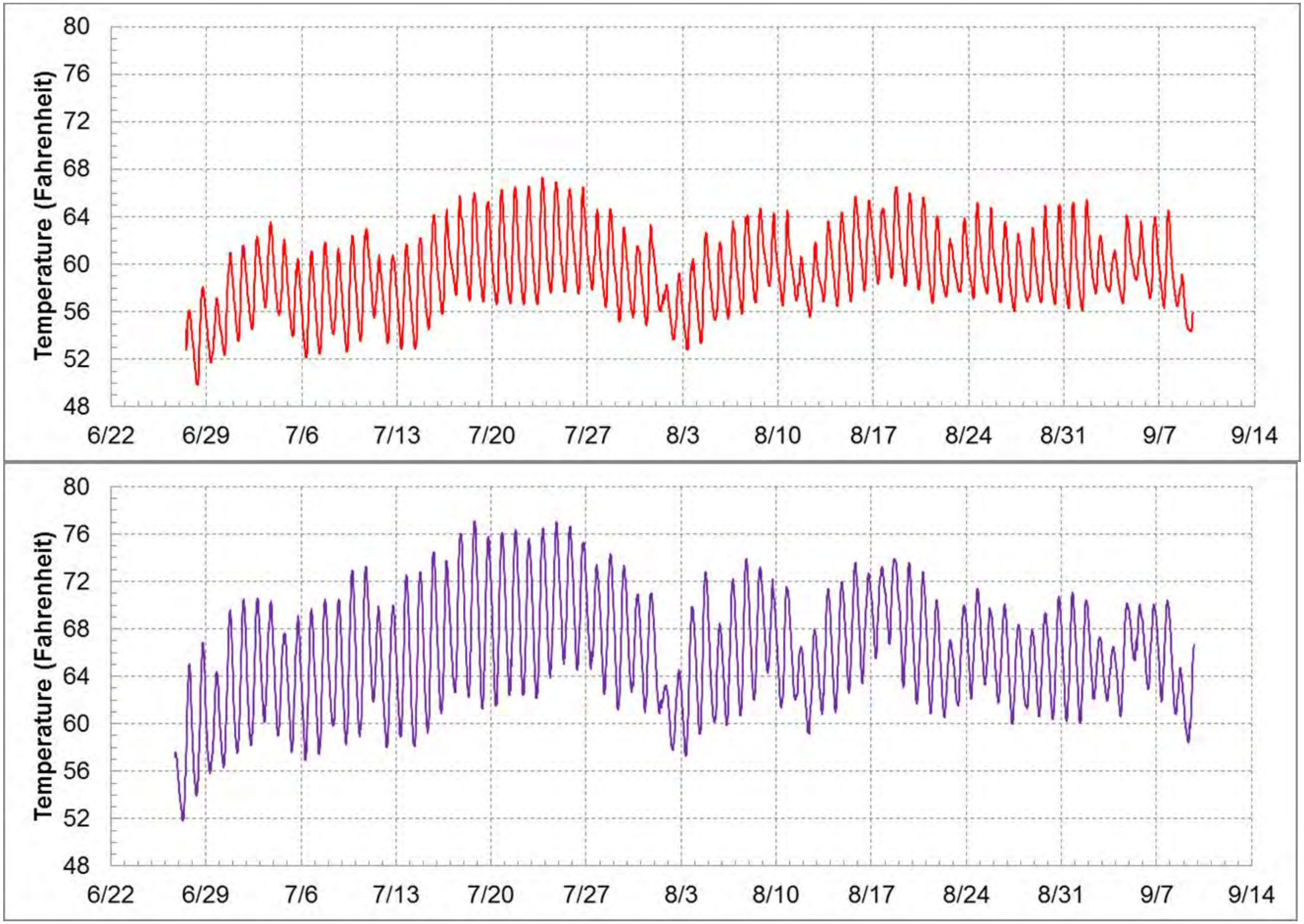


Figure 6. Continuous temperature at logger MC-T6 (top) in upper Mill Creek and logger MC-T1 (bottom) in lower Mill Creek, June 26-27 to September 9, 2013.

3 QUAL2K Model Development

EPA and DEQ selected the QUAL2K model to simulate temperatures in Mill Creek. QUAL2K is supported by EPA and has been used extensively for TMDL development and point source permitting across the country. The QUAL2K model is suitable for water temperatures in small rivers and creeks. It is a one-dimensional uniform flow model with the assumption of a completely mixed system for each computational cell. QUAL2K assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the longitudinal direction of flow. The heat budget and temperature are simulated as a function of meteorology on a diel time scale. Heat and mass inputs through point and nonpoint sources are also simulated. The model allows for multiple waste discharges, water withdrawals, nonpoint source loading, tributary flows, and incremental inflows and outflows. QUAL2K simulates in-stream temperatures via a heat balance that accounts "for heat transfers from adjacent elements, loads, withdrawals, the atmosphere, and the sediments" (Chapra et al. 2008, p. 19).

The current release of QUAL2K is version 2.11b8 (January 2009). The model is publicly available at http://www.epa.gov/athens/wwqtsc/html/QUAL2K.html and http://qual2k.com/. Additional information regarding QUAL2K is presented in the *Quality Assurance Project Plan for Montana TMDL Support: Temperature Modeling* (Tetra Tech 2012).

The following describes the process that was used to setup, calibrate, and validate the QUAL2K models for Mill Creek.

3.1 Model Framework

The QUAL2K model (Chapra et al. 2008) was selected for modeling Mill Creek. The modeling domain was limited to the main stem below MC-T6, which is approximately RM 8.46, to the mouth on Fred Burr Creek (refer back to **Figure 2** for a map of the Mill Creek watershed).

Data were specifically collected to support the QUAL2K model for the Mill Creek. Flow, shade, and continuous temperature were acquired during June, August, and September 2013. In addition, flow and temperature data were collected at a major tributary to Mill Creek.

3.2 Model Configuration and Setup

Model configuration involved setting up the model computational grid and setting initial conditions, boundary conditions, and hydraulic and light and heat parameters. All inputs were longitudinally referenced, allowing spatial and continuous inputs to apply to certain zones or specific stream segments. This section describes the configuration and key components of the model.

3.2.1 Modeling Time Period

The calibration and validation steady-state model periods were June 28, 2013 and September 8, 2013, respectively. These dates were selected since they had the most complete datasets that could be used for model setup, calibration, and validation. Flow and logger temperature data were available for most sites on those dates and weather data were also available for those dates.

Calibration Period: The calibration period was June 28, 2013 and was selected due to the availability of flow and temperature data (**Appendix A**). Flow was monitored at the loggers on June 26-27, 2013. The first full day of temperature data for all the loggers was June 28, 2013. Flows monitored on June 26-27 were assumed to be representative of flow conditions on June 28, 2013 as no precipitation was recorded July 26-28, 2013[3].

Validation Period: The validation period was September 8, 2013 and was selected due to the availability of flow and temperature data (**Appendix A**). Flow was monitored at the loggers on September 9, 2013. The last full day of temperature data for all the loggers was September 8, 2013. Flows monitored on September 9, 2013 were assumed to be representative of flow conditions on September 8, 2013 as no precipitation was recorded September 8-9, 2014.

3.2.2 Segmentation

Segmentation refers to discretization of a waterbody into smaller computational units (e.g., reaches and elements). Reaches in QUAL2K have constant hydraulic characteristics (e.g. slope, bottom width) and each reach is further divided into elements that are the fundamental computational units in QUAL2K. The Mill Creek mainstem was segmented into reach lengths of 0.19 mile (300 meters), which were sufficient to incorporate any point inputs to the waterbody and to maintain Courant stability. In addition since shading is applied at the reach level this allowed for better representation of the spatial variability observed in the Shade Model results along Mill Creek (see **Appendix A** for shade modeling discussion). One major tributary, Sheafman Creek, was represented through boundary condition designation (see **Section 3.2.4** for a discussion of boundary conditions). Refer back to **Figure 2** for a map that shows the Mill Creek mainstem and its tributaries.

3.2.3 Streamflow and Hydraulics

The flow rates were estimated through flow mass balance (continuity) calculations at the loggers and other sites where flows were monitored. The rating curve method was used to relate the depth and the velocity to the flow rate in a reach. This method requires specification of the empirical coefficients and exponents based on numerous measurements of depths, velocities, and flows. Due to the limited amount of field data, coefficients of the rating curve were treated to be the calibration parameters against the observed depths and velocities.

Typical exponents for velocity (0.43) and depth (0.45) are described in the QUAL2K manual (Chapra et al. 2008). Exponents were also calculated for two nearby U.S. Geological Survey (USGS) gages of similar size to Mill Creek, which is 40.0 square miles (**Table 3)**. The exponents were set to the averages calculated from the three USGS gages: 0.40 for velocity and 0.33 for depth.

Table 3. Calculated exponents for nearby USGS gages

Gage ID	Gage name	Drainage area (square miles)	Exponents	
			Velocity	Depth
12327100	Fred Burr Creek near Philipsburg, MT	15.70	0.47	0.38
13305700	Dahlonega Creek at Gibbonsville, ID	32.00	0.34	0.28

[3] Precipitation data reported for June 28, 2013 at the Smith Creek RAWS were erroneous. Weather data were also retrieved from National Weather Service station 243885, which is 6.7 miles south of the mouth of Mill Creek, to verify that no precipitation occurred at or just before the selected calibration period.

3.2.4 Boundary Conditions

Boundary conditions represent external contributions to the waterbody being modeled. A flow and temperature input file was therefore configured for inputs to Mill Creek. Boundary conditions were specified at the upstream terminus of Mill Creek (at logger MC-T6), for the Sheafman Creek confluence with Mill Creek, and for diffuse sources along the creek. These are further discussed in the following sections.

3.2.4.1 Headwater (Upstream) Boundary

QUAL2K requires specification of the headwater flow and temperature. Diurnal temperatures (June 28, 2013 for calibration and September 8, 2013 for validation) at the upstream boundary were specified using observed data from the in-stream logger at site MC-T6. A flow of 88.4 cubic feet per second (cfs) was specified for the calibration period and 9.82 cfs was specified for the validation period. **Figure 7** shows the headwater temperatures specified in the model.

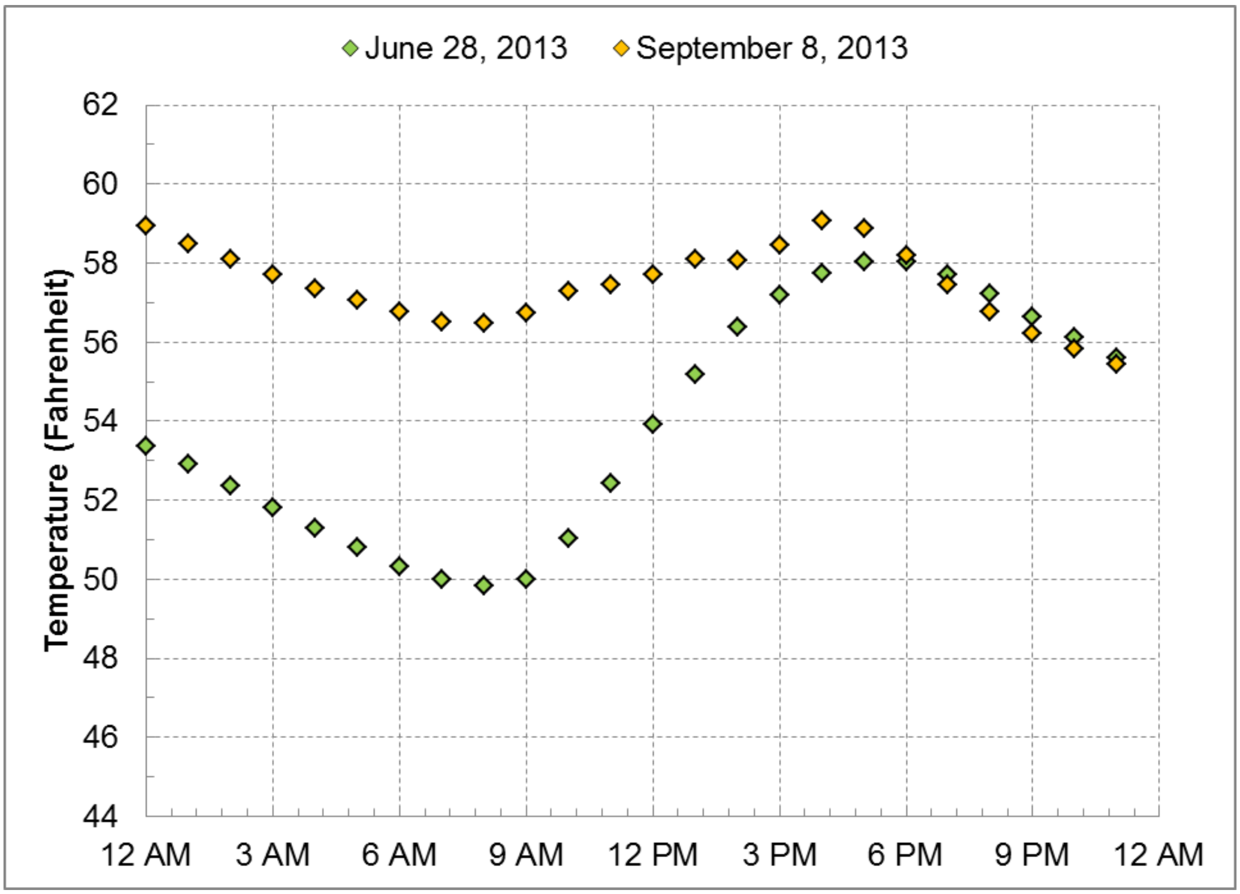


Figure 7. Diurnal temperature at the headwaters to Mill Creek.

3.2.4.2 Tributary and Irrigation Inputs

There are many small tributaries in the watershed; however, monitoring data were available for only one major tributary – Sheafman Creek (**Figure 2**). **Table 4** shows the flow and temperature assigned to Sheafman Creek.

In addition to tributary inputs, irrigation withdrawals from Mill Creek were also identified[4] (see **Appendix A** for a discussion of these withdrawals) and assigned in the model. A total of 22.4 cfs was withdrawn from Mill Creek on June 28, 2013, while 5.00 cfs was withdrawn on September 9, 2013. These withdrawals were used in the model (rows identified as *irrigation withdrawal* in **Table 4**). More information on the irrigation withdrawal can be found in **Appendix A**.

Table 4. QUAL2K model flow and temperature inputs to Mill Creek - Tributary and irrigation withdrawals

Description	Location (RM)	Point sources [a] Abstraction (cfs)	Point sources [a] Inflow (cfs)	Temperature [b] Daily mean (°F)	Temperature [b] ½ daily range (°F)	Temperature [b] Time of maximum (hour)
June 28, 2013						
irrigation withdrawal	8.03	2.00	--	--	--	--
irrigation withdrawal	8.01	1.95	--	--	--	--
irrigation withdrawal	7.92	4.60	--	--	--	--
irrigation withdrawal	7.72	2.25	--	--	--	--
irrigation withdrawal	6.92	4.25	--	--	--	--
irrigation withdrawal	6.69	4.25	--	--	--	--
irrigation withdrawal	6.25	1.38	--	--	--	--
irrigation withdrawal	5.87	1.75	--	--	--	--
Sheafman Creek	1.91	--	10.47	54.0	6.6	5:00 PM
September 8, 2013						
irrigation withdrawal	8.03	--	--	--	--	--
irrigation withdrawal	8.01	--	--	--	--	--
irrigation withdrawal	7.92	1.00	--	--	--	--
irrigation withdrawal	7.72	1.00	--	--	--	--
irrigation withdrawal	6.92	2.25	--	--	--	--
irrigation withdrawal	6.69	--	--	--	--	--
irrigation withdrawal	6.25	0.75	--	--	--	--
irrigation withdrawal	5.87	--	--	--	--	--
Sheafman Creek [c]	1.91	--	--	--	--	--

Notes
°F = degrees Fahrenheit; cfs = cubic feet per second; RM = river mile.
a. Points sources represent abstractions (i.e., withdrawals) or inflows. Each point source can be an abstraction or an inflow.
b. The daily mean temperature, one-half of the daily range of temperatures across the model period, and time of the maximum hourly temperature are only applicable to point source inflows.
c. Sheafman Creek ran dry and was not simulated during the validation period.

3.2.4.3 Diffuse Sources

Groundwater, irrigation return flows, and other sources of water not accounted for in the tributaries can be specified along the length of the waterbody using the Diffuse Sources worksheet in the QUAL2K model. A flow balance was constructed using the observed flows along Mill Creek and its tributary. The amount of diffuse flow along Mill Creek was calculated for June 28, 2013 and September 8, 2013.

[4] Jordan Tollefson (TMDL Planner, DEQ) identified 13 ditches that withdrawal water from Mill Creek for irrigation purposes, based on personal communications with Sandy Schlotterbeck and David Allen of the Mill Creek Irrigation District on February 5th, 10th, and 13th, 2014.

The initial diffuse flow temperature was selected as the maximum reported groundwater temperature (range: 44.1° F to 60.3° F) from nearby wells, which was further evaluated during calibration. A diffuse inflow temperature of 59.0° F was selected to account for potentially warmer, open channel irrigation return flows. The final flow and water temperature assignment are shown below in **Table 5**.

Table 5. QUAL2K model flow and temperature inputs to Mill Creek - Diffuse sources

Segment	Location [a] Upstream (RM)	Downstream (RM)	Diffuse Abstraction (cfs)	Diffuse Inflow Inflow (cfs)	Temp (°F)
June 28, 2013					
MC-T6 to MC-T5	8.46	6.84	--	1.93	59.0
MC-T5 to MC-T4	6.83	5.71	20.01	--	--
MC-T4 to MC-T3	5.70	4.60	4.11	--	--
MC-T3 to MC-T2	4.60	2.85	--	6.96	59.0
MC-T2 to Sheafman Creek	2.84	1.92	--	8.29	59.0
Sheafman Creek to MC-T1	1.91	0.54	--	--	--
MC-T1 to mouth	0.53	0.00	--	--	--
September 8, 2013					
MC-T6 to MC-T5	8.46	6.84	3.99	--	
MC-T5 to MC-T4	6.83	5.71	--	0.63	59.0
MC-T4 to MC-T3	5.70	4.60	1.36	--	
MC-T3 to MC-T2	4.60	2.85	--	3.55	59.0
MC-T2 to Sheafman Creek	2.84	1.92	2.83	--	
Sheafman Creek to MC-T1	1.91	0.54	--	1.41	59.0
MC-T1 to mouth	0.53	0.00	--	--	

Notes
°F = degrees Fahrenheit; cfs = cubic feet per second; RM = river mile.
a. Upstream and downstream termini of segments.

3.2.5 Meteorological Data

Forcing functions for heat flux calculations are determined by the meteorological conditions in QUAL2K. The QUAL2K model requires hourly meteorological input for the following parameters: air temperature, dew point temperature, wind speed, and cloud cover. One of the nearest weather stations in the vicinity of the Mill Creek watershed is the Smith Creek RAWS (National Weather Service ID 242912), which is 7.3 miles to the north of the mouth of Mill Creek at an elevation of 5,560 feet above mean sea level. The other nearby weather station is in Hamilton (National Weather Service ID 243885); however, its dataset does not include hourly data for the pertinent weather parameters. Since the Smith Creek RAWS has a complete hourly dataset, the RAWS was used to develop the QUAL2K model (refer to Appendix A for more discussion of these two weather stations).

The Smith Creek RAWS records hourly air temperature, dew point temperature, wind speed and solar radiation. Therefore, the Smith Creek RAWS hourly observed meteorological data were used to develop the QUAL2K model after appropriate unit conversions.

The wind speed measurements at the Smith Creek RAWS were measured at 20 feet (6.10 meters) above the ground. QUAL2K requires that the wind speed be at a height of 7 meters. The wind speed measurements ($U_{w,z}$ in meters per second) taken at a height of 6.10 meters (z_w in meters) were converted to equivalent conditions at a height of *z* = 7 meters (the appropriate height for input to the evaporative heat loss equation), using the exponential wind law equation suggested in the QUAL2K user's manual (Chapra et al. 2008):

$$U_w = U_{wz}\left(\frac{z}{z_w}\right)^{0.15}$$

3.2.6 Shade Data

The QUAL2K model allows for spatial and temporal specification of shade, which is the fraction of potential solar radiation that is blocked by topography and vegetation. A Shade Model was developed and calibrated for Mill Creek. The calibrated Shade Model was first run to simulate shade estimates for June 28, 2013 to simulate hourly shade every 49 feet (15 meters, the resolution of the Shade Model) along Mill Creek. Reach-averaged integrated hourly effective shade results were then computed at every 0.19 mile (300 meters; i.e., each reach). The reach-averaged results were then input into each reach within the QUAL2K model. A more detailed discussion on the shade modeling can be found under **Appendix A**.

3.3 Model Evaluation Criteria

The goodness of fit for the simulated temperature using the QUAL2K model was summarized using the absolute mean error (AME) and relative error (REL) as a measure of the deviation of model-predicted temperature values from the measured values. These model performance measures were calculated as follows:

$$AME = \frac{1}{N}\sum_{n=1}^{n} |P_n - O_n|$$

$$\text{REL} = \frac{\sum_{n=1}^{n} |P_n - O_n|}{\sum_{n=1}^{n} O_n}$$

These performance measures are detailed later in the section in evaluation of the model calibration.

3.4 Model Calibration and Validation

The time periods selected for calibration and validation were June 28, 2013 and September 8, 2013; the travel times were 6 hours and three days, respectively. These dates were selected as they had the most comprehensive datasets available for modeling and corresponded to the synoptic study done for Mill Creek, which included collecting flow, temperature, and shade.

Flow, depth, velocity and temperature data were available at six locations along the main stem of Mill Creek. **Table 6** shows the monitoring sites used for calibration.

Table 6. Temperature calibration locations

Site name	Distance (river mile)	Available Data	Source
MC-6	8.47	Flow, depth, velocity, and temperature	Tetra Tech
MC-5	6.84	Flow, depth, velocity and temperature	Tetra Tech
MC-4	5.71	Flow, depth, velocity and temperature	Tetra Tech
MC-3	4.60	Flow, depth, velocity, and temperature	Tetra Tech
MC-2	2.85	Flow, depth, velocity, and temperature	Tetra Tech
MC-1	0.56	Flow, depth, velocity, and temperature	Tetra Tech

The first step for calibration was adjusting the flow balance and calibrating the system hydraulics. A flow balance was constructed for the calibration date. This involved accounting for all the flow in the system. Observed flows along Mill Creek, Sheafman Creek, and withdrawals were used to estimate the amount of diffuse flow along the system.

After the mass balance of the flow rates, the modeled velocity and depth were simulated using the previously described rating curve method. To summarize, the exponents of the rating curve for the depth and the velocity were set to be 0.33 and 0.40 respectively. While the exponents were not varied during the model calibration, the rating curve coefficients were modified and evaluated against the observed data. The model results indicated a reasonable model representation. The calibrated coefficients were deemed appropriate since they were based upon observed data and yielded reasonable fits of velocity and depth. The model results indicated a reasonable model simulation as shown in **Figure 8** and **Figure 9**.

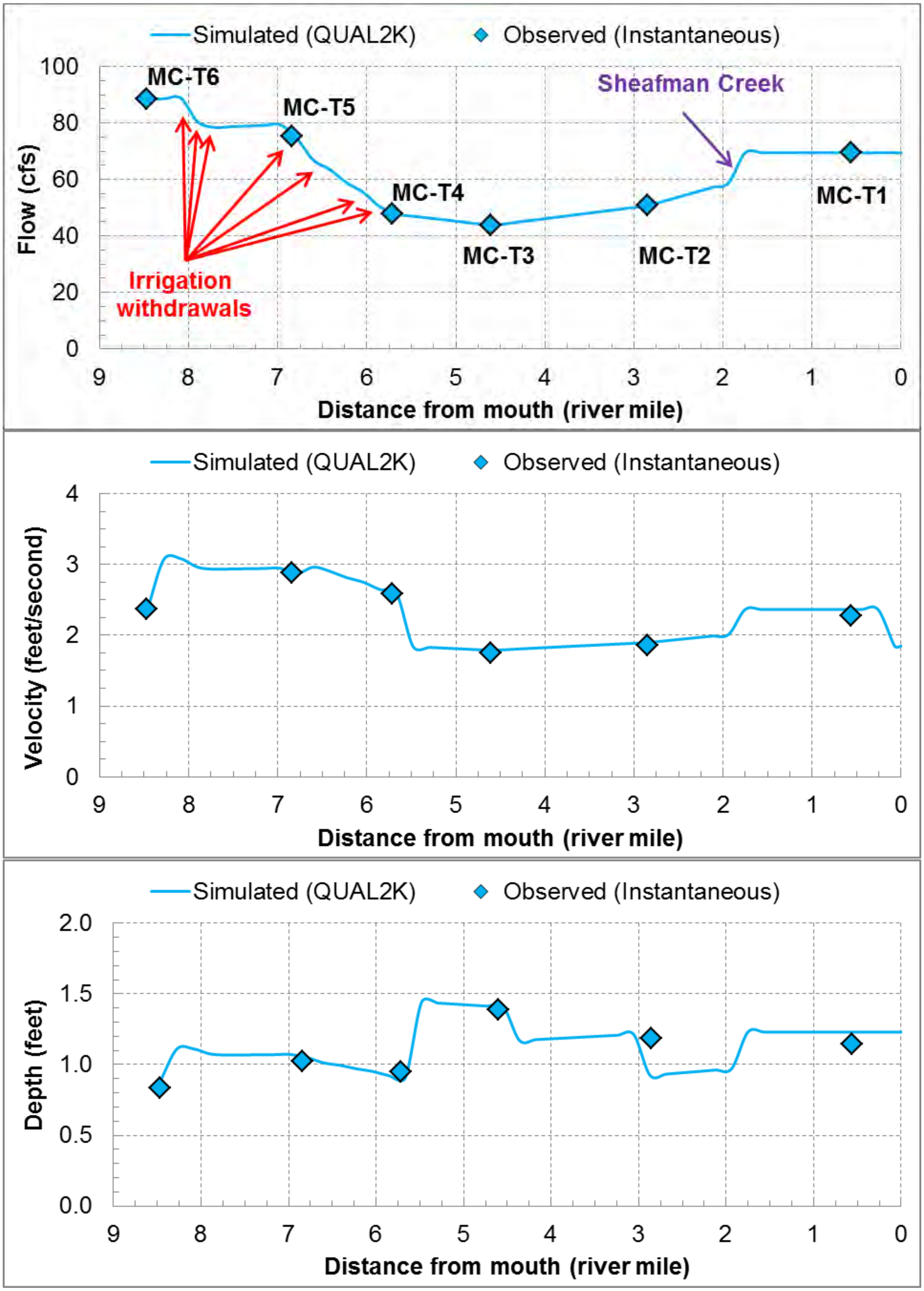


Figure 8. Observed and predicted flow, velocity, and depth on June 28, 2013 (calibration).

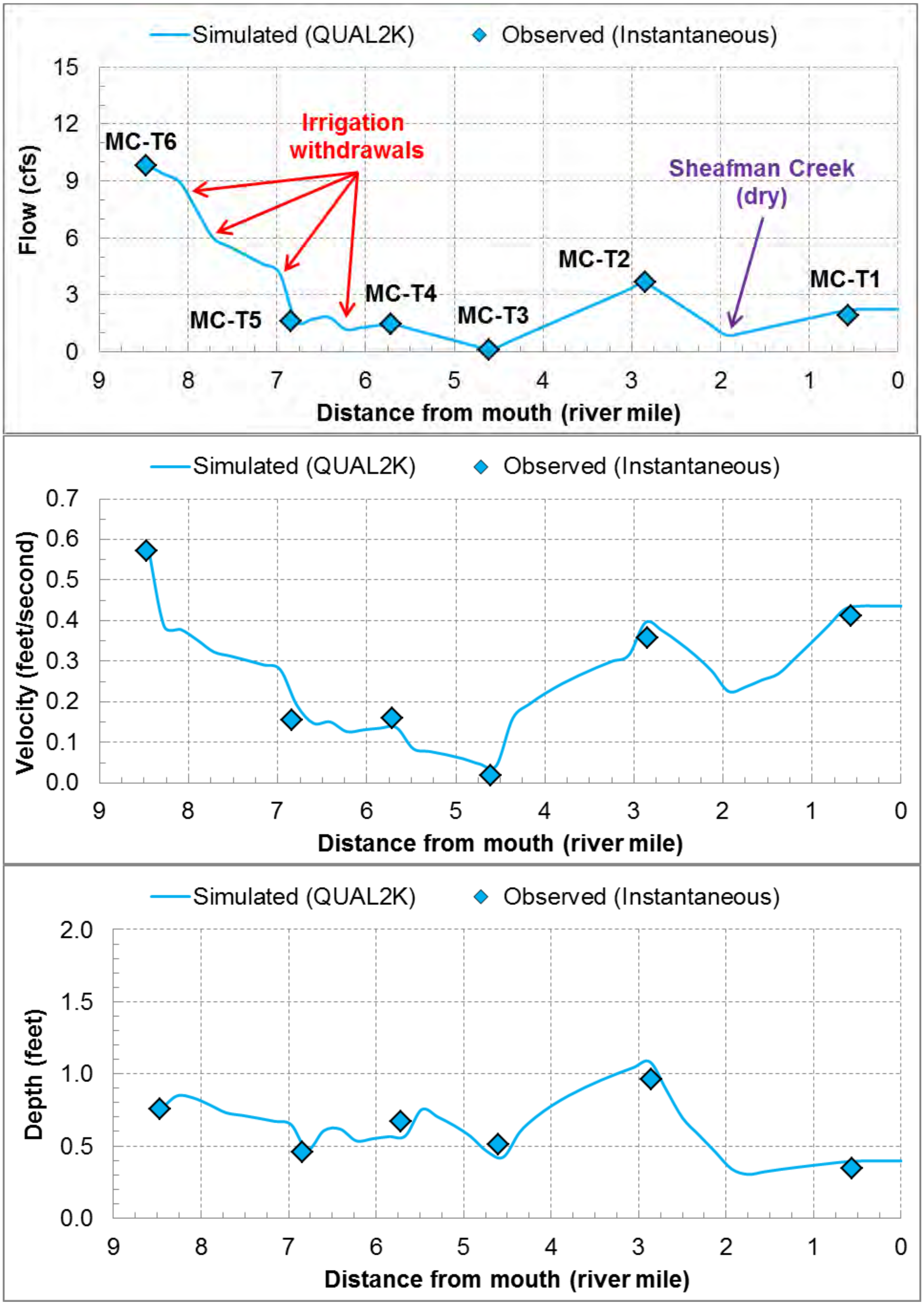


Figure 9. Observed and predicted flow, velocity, and depth on September 8, 2013 (validation).

Once the system hydraulics were established, the model was then calibrated for water temperature. Temperature calibration included calibrating the model by adjusting the light and heat parameters with available data. A discussion of the solar radiation model and calibration along with other heat related inputs that were selected is presented below.

Hourly solar radiation is an important factor that affects stream temperature. The QUAL2K model does not allow for input of solar radiation. Instead the model calculates short wave solar radiation using an atmospheric attenuation model. For Mill Creek, the Ryan-Stolzenbach model was used to calculate the solar radiation. The calculated solar radiation values (without stream shade) for the calibration and validation were compared with observed solar radiation measurements at the Smith Creek RAWS. **Figure 10** shows the observed and predicted solar radiation for the calibration. The Ryan-Stolzenbach atmospheric transmission coefficient was set at 0.90 for the calibration to reflect the atmospheric conditions (i.e., cloudy) to minimize the deviation between the observed and modeled short wave solar radiation.

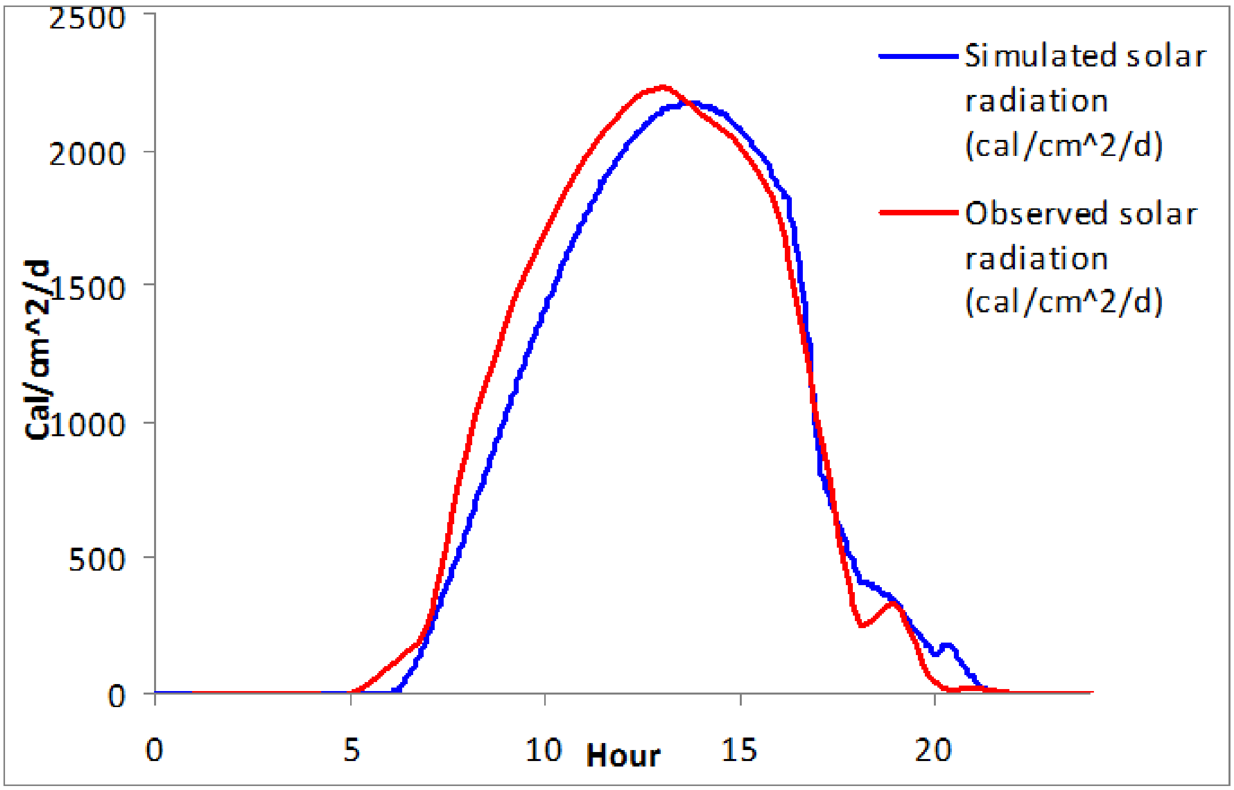


Figure 10. Observed and predicted solar radiation on June 28, 2013 (calibration).

The longwave solar radiation model and the evaporation and air conduction/convections models were kept at the default QUAL2K settings. The solar radiation settings are shown in **Table 7**.

Table 7. Solar radiation settings

Parameter	Value
Solar Shortwave Radiation Model	
Atmospheric attenuation model for solar	Ryan-Stolzenbach
Ryan-Stolzenbach solar parameter (used if Ryan-Stolzenbach solar model is selected)	
Atmospheric transmission coefficient [a]	0.90
Downwelling atmospheric longwave infrared radiation	
Atmospheric longwave emissivity model	Brutsaert
Evaporation and air convection/conduction	
Wind speed function for evaporation and air convection/conduction	Adams 2

Note: a. The range of atmospheric transmission coefficients is 0.70 to 0.91 and the QUAL2K model default is 0.80 (Chapra et al. 2008).

The sediment heat parameters were also evaluated for calibration. In particular the sediment thermal thickness, sediment thermal diffusivity, and sediment density were adjusted during calibration. The sediment thermal thickness was increased from the default value of 10 cm to 20 cm, and the sediment heat capacity of all component materials of the stream was set to 0.4 calories per gram per degree Celsius, which is the QUAL2K default (Chapra et al. 2008).

The sediment density was set to 2.04 grams per cubic centimeter (g/cm^3). Based on the field photographs, the surface layer of the stream substrate was estimated to be composed of 80 percent rock gravel and 20 percent of silt and clay. The following calculation was conducted:

$$\text{sediment density} = (\text{ratio} * \text{density})_{\text{gravel}} + (\text{ratio} * \text{density})_{\text{silt and clay}}$$
$$= (0.80 * 2.00\ g/cm^3) + (0.20 * 2.20\ g/cm^3)$$
$$= 2.04\ g/cm^3$$

where 2.00 g/cm^3 is the density of gravel and 2.20 g/cm^3 is typical of clay and silt densities.

The sediment thermal diffusivity was set to a value of 0.0112 square centimeters per second (cm^2/s; Chapra et al. 2008). The following calculation was conducted:

$$\text{thermal diffusivity} = (\text{ratio} * \text{thermal diffusivity})_{\text{rock+gravel}} + (\text{ratio} * \text{thermal diffusivity})_{\text{sand}} + (\text{ratio} * \text{thermal diffusivity})_{\text{silt}}$$
$$= (0.80 * 0.0118\ cm^2/s) + (0.11 * 0.0079\ cm^2/s) + (0.09 * 0.0098\ cm^2/s)$$
$$= 0.0112\ cm^2/s$$

where 0.118 cm^2/s is the thermal diffusivity of rock, 0.0079 cm^2/s is the thermal diffusivity of sand, and 0.0098 cm^2/s is the thermal diffusivity of clay, which is assumed to be representative of silt.

These adjustments helped in improving the minimum temperatures simulated.

Calibration was followed by validation. The validation provides a test of the calibrated model parameters under a different set of conditions. Only those variables that changed with time were changed during validation to confirm the hydraulic variables. This included headwater and tributary in-stream temperatures, air and dew point temperatures, wind speed, cloud cover, solar radiation, and shade. The atmospheric transmission coefficient was changed from 0.90 in the calibration, which represents cloudy conditions, to 0.70 in the validation, which represents clear conditions for much of the day. All other inputs were based on observed data June 28, 2014. Groundwater temperatures, for which there were no direct observed data, were unchanged since they are not expected to vary greatly. **Figure 11** and **Figure 12** show the calibration and validation results along Mill Creek. The temperature calibration and validation statistics of the average, maximum, and minimum temperatures are shown in **Table 8** and **Table 9**, respectively.

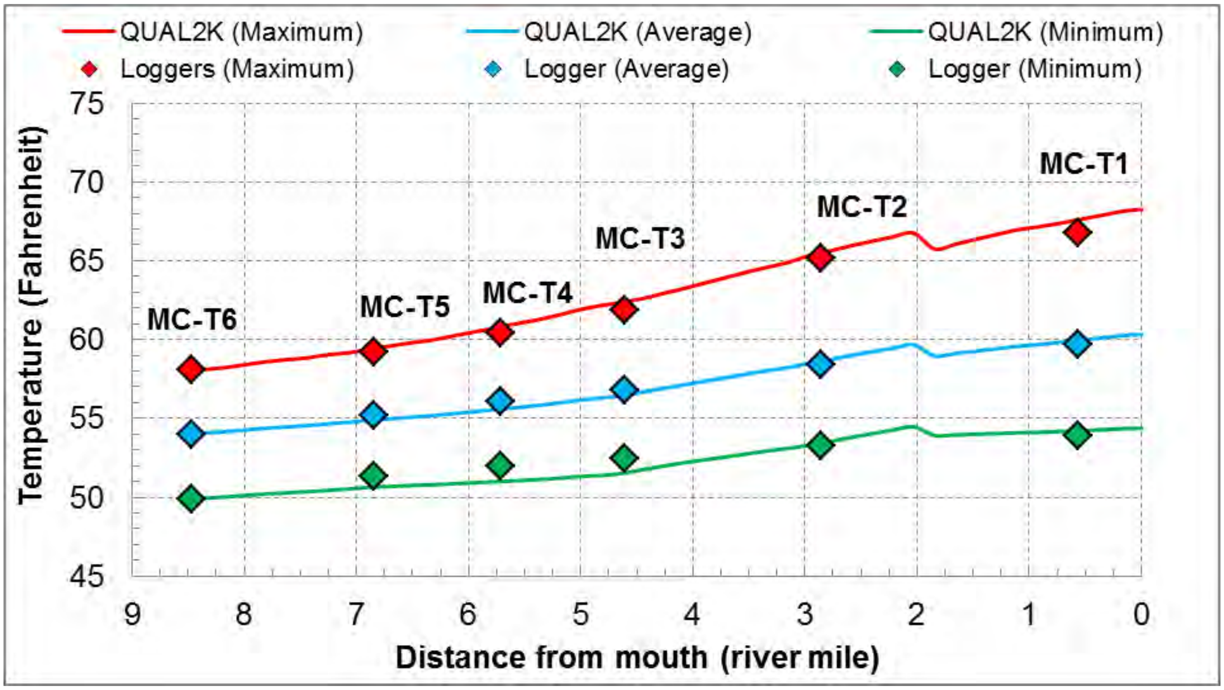


Figure 11. Longitudinal profile of the temperature calibration (June 28, 2013).

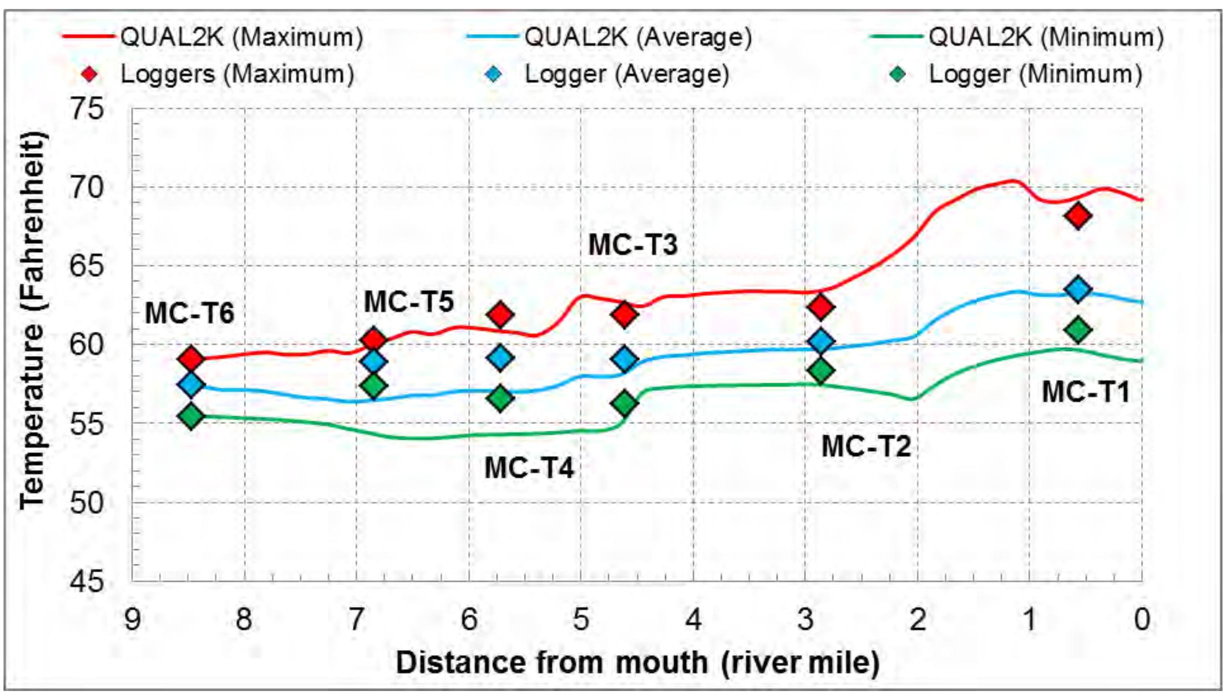


Figure 12. Longitudinal profile of the temperature validation (September 8, 2013).

Table 8. Calibration statistics of observed versus predicted water temperatures

Site name	RM	Average daily temperature		Maximum daily temperature		Minimum daily temperature	
		AME (°F)	REL (%)	AME (°F)	REL (%)	AME (°F)	REL (%)
MC-T6	8.47	--	--	--	--	--	--
MC-T5	6.84	0.30	0.5%	0.23	0.4%	0.71	1.4%
MC-T4	5.71	0.52	0.9%	0.33	0.5%	1.02	2.0%
MC-T3	4.60	0.35	0.6%	0.52	0.8%	0.92	1.8%
MC-T2	2.85	0.29	0.5%	0.49	0.7%	0.28	0.5%
MC-T1	0.56	5.46	9.1%	0.90	1.3%	0.29	0.5%
Overall Calibration		**1.38**	**2.4%**	**0.49**	**0.8%**	**0.64**	1.2%

Note: AME = absolute mean error; REL = relative error; RM = river mile.

Table 9. Validation statistics of observed versus predicted water temperatures

Site name	RM	Average daily temperature		Maximum daily temperature		Minimum daily temperature	
		AME (°F)	REL (%)	AME (°F)	REL (%)	AME (°F)	REL (%)
MC-T6	8.47	--	--	--	--	--	--
MC-T5	6.84	2.41	4.1%	0.29	0.5%	2.98	5.2%
MC-T4	5.71	2.05	3.5%	0.94	1.5%	2.26	4.0%
MC-T3	4.60	0.97	1.6%	0.85	1.4%	1.19	2.1%
MC-T2	2.85	0.09	0.2%	1.22	2.0%	0.95	1.6%
MC-T1	0.56	0.27	0.4%	1.25	1.8%	1.23	2.0%
Overall Validation		**1.16**	**1.9%**	**0.91**	**1.4%**	**1.72**	**3.0%**

Note: AME = absolute mean error; REL = relative error; RM = river mile.

Based on the calibration results, the model is able to simulate the flow, depth, and velocity and the minimum, mean, and maximum temperatures reasonably well. The model over-predicts the minimum, mean, and maximum temperature at all loggers though the AMEs of the maximums (range: 0.23° F to 0.90° F) are considerably smaller than the AMEs of the averages (range: 0.29° F to 5.46° F) and the minimums (range: 0.28° F to 1.02° F) (**Table 8**). The overall calibration results showed an overall 0.8 percent relative error with an AME of 0.49° F for the maximum temperatures; thus, the model simulation is good.

The model results for the validation are similar to those of the calibration. The model often over-predicts the minimum and mean temperatures and often under-predicts the maximum temperatures (**Table 9**). However, the AMEs of the maximums (range: 0.29° F to 1.25° F) are considerably smaller than the AMEs of the averages (range: 0.09° F to 2.41° F) and the minimums (range: 0.95° F to 2.98° F). The overall validation results showed an overall 1.4 percent relative error with an AME of 0.91° F for the maximum temperatures.

3.5 Model Sensitivity

Sensitivity analysis measures the relative importance of parameters, such as shade and water withdrawals, on model response. Model sensitivity was generally evaluated by making changes to shade[5] and water use[6] (i.e., the key thermal mechanisms [Tetra Tech 2012]) in separate model runs and evaluating the model response. Model sensitivity analyses with similar QUAL2K models for streams in western Montana (Fortine, Wolf, and McGregor creeks) suggest that the QUAL2K models developed with the data typically available for the Montana temperature projects are sometimes not sensitive to changes in water use but are sensitive to changes in shade. This is however stream/rivers specific, thus the sensitivity of water withdrawals and shade were explored with the Mill Creek QUAL2K model during model development and the results were generally consistent with previous Montana streams QUAL2K projects.

[5] To assess model sensitivity to shade, all vegetation was converted to high density trees (with the exception of roads and hydrophytic shrubs) to represent the maximum potential shade.

[6] To assess model sensitivity to water withdrawals, the point source abstractions representing the withdrawals were removed and the existing condition model was run to represent the maximum achievable change in water temperatures from changes in water use.

4 Model Scenarios and Results

The Mill Creek QUAL2K model was used to evaluate in-stream temperature response associated with multiple management scenarios. **Table 10** summarizes the alterations for each model scenario. The following subsections present discussions of the modifications to the QUAL2K models and the results for each scenario.

Table 10. QUAL2K model scenarios for Mill Creek

Scenario [a]		Description	Rationale
Baseline Scenario			
1	Existing Condition	Summer shade (August 12, 2013) and irrigation practices (average of August 12-13, 2013) under low-flows[b] and summer weather conditions (August 15,2013)	The baseline model simulation from which to construct the other scenarios and compare the results against.
Water Use Scenario			
2	15 % reduction in withdrawals	Reduce existing withdrawals by 15 percent	Represent application of conservation practices for agricultural and domestic water use.
Shade Scenario			
3	Shade increased to reference levels	Increased shading along two segments: (1) from RMs 7.5 to 4.5 to be equivalent to MC-T3, and (2) from RM 4.5 to the mouth to be equivalent to MC-T2.	Represent application of conservation practices for riparian vegetation.
Improved Flow and Shade			
4	Improved flow and shade	Existing conditions with 15% reduction in withdrawals (scenario 2) and increase to reference levels (scenario 3).	Represent application of conservation practices for water withdrawals and riparian vegetation.

Notes

a. Scenarios were developed in accordance with electronic correspondence from the DEQ project manager Jordan Tollefson to Tetra Tech's project manager Ron Steg on April 15-29, 2014.

b. Flows from the calibration model, which were field-monitored on June 26-27, 2013, were reduced 79 percent to represent August flow conditions, based in part upon field measured flows on June 26-27, 2013 and August 12-13, 2013 and flow relationships at a surrogate USGS gage (12342500 West Fork Bitterroot River, near Connor, MT).

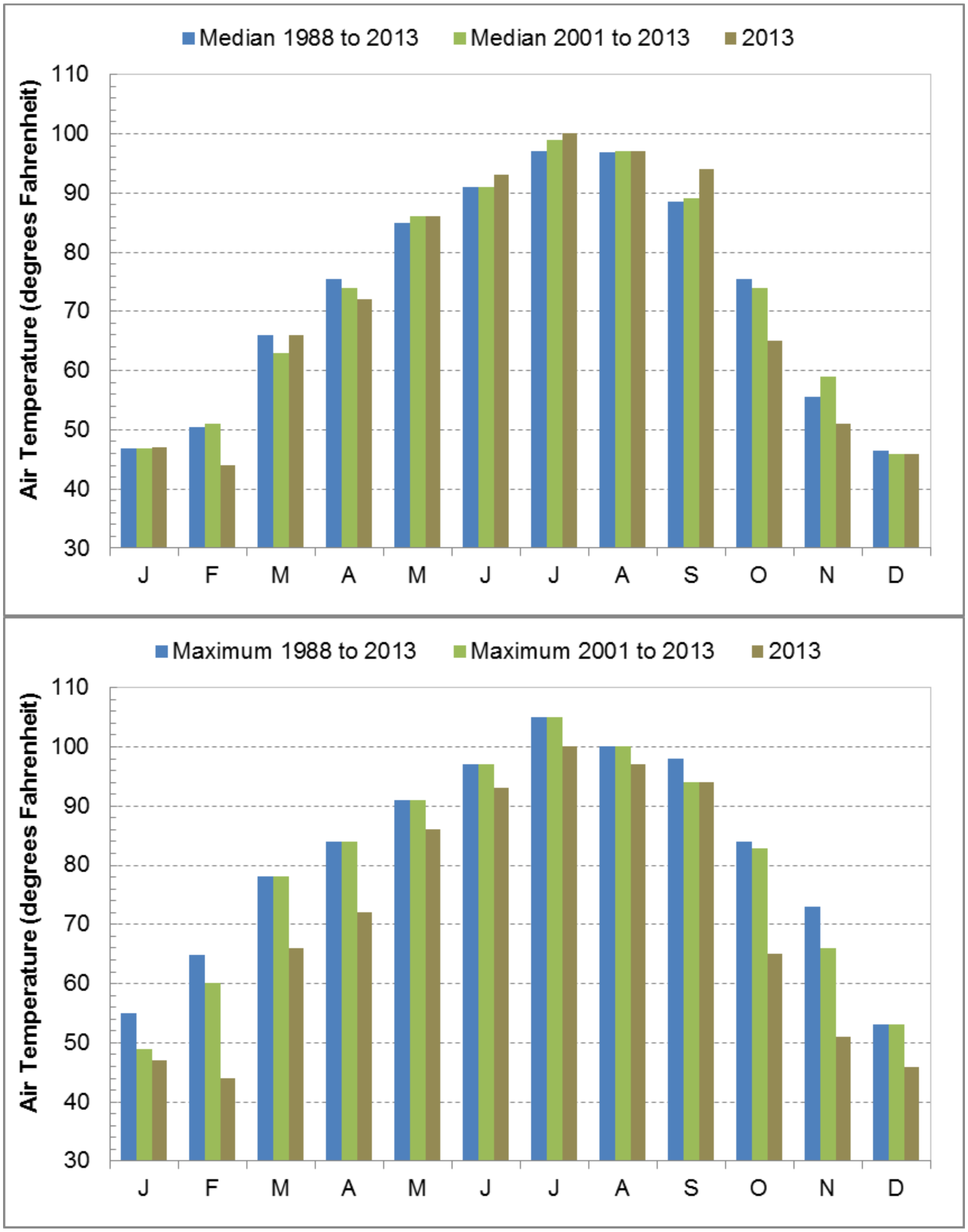
4.1 Baseline Scenario

The baseline model (scenario 1) serves as the model simulation from which to construct the other scenarios and compare the results against. The baseline scenario was run using flow and weather conditions from August 12-15, 2013 to create a synthetic August condition.

4.1.1.1 Weather Data

The Smith Creek RAWS has hourly data available for the period from February 2001 through May 2014. Since the weather data extends only for a period of 14 years, a nearby station with long-term meteorological data (Missoula International Airport [1988-2013]) was queried to confirm if the years from 2001 to 2013 were (1) not anomalously warm or cold and (2) similar to the overall historical normal. Additionally, comparisons with the year 2013 (during which the QUAL2K model calibration period occurs) were made to ensure that 2013 was not an anomalous year. The long-term monthly median and maximum air temperatures for the period from 2001 to 2013 and for the year 2013 were estimated to be similar to the overall period from 1988 through 2013 (**Figure 13**)[7]. While the monthly maximum air temperatures in the summer of 2013 were cooler than the monthly long-term maximum of monthly maximum air temperatures of the years 1988-2013, they were warmer in some months as compared with the monthly long-term median of monthly maximum air temperatures of the years 1988-2013 (**Figure 13**). Therefore, since neither the period from 2001 through 2013 nor the summer of 2013 was substantially anomalous, it is appropriate to use the Smith Creek RAWS data for QUAL2K modeling.

[7] Hourly average air temperatures were obtained for the Missoula International Airport (KMSO). Monthly maximum air temperatures were calculated for each month from January 1988 through December 2013 using the hourly average air temperatures. Monthly long-term medians and maximums were calculated from the 26 years of monthly maximums of hourly average air temperatures.



Note: Hourly average air temperatures were obtained for the Missoula International Airport (KMSO). Monthly maximum air temperatures were calculated for each month from January 1988 through December 2013 using the hourly average air temperatures. Monthly long-term medians and maximums were calculated from the 26 years of monthly maximums of hourly average air temperatures.

Figure 13. Long-term median (chart on top) and maximum (chart on bottom) of monthly maximum air temperature at Missoula.

4.1.1.2 Synthetic August Weather

Weather conditions from August 15, 2013 were used for the baseline model. While the mid-season flows were monitored on August 12-13, 2014, the solar radiation from these days indicated considerable cloud cover. To simulate a more typical sunny August day, the solar radiation from August 15, 2013 was selected as the most representative sunny day in mid-August, though there were some clouds in the evening. All QUAL2K model inputs for weather were selected from the Smith Creek RAWS for August 15, 2013.

4.1.1.3 Synthetic Low-Flow

No continuous flow datasets are available in the Mill Creek watershed. The closest continuously recording USGS gage in a watershed of similar size is gage 12353650 (West Fork Bitterroot River at USGS gage 12353650; water years 1941-2013). Daily average flows for the surrogate gage on the days that instantaneous flow data were collected from Mill Creek are presented in **Section A-6** of **Appendix A**.

The Mill Creek model was calibrated to June 28, 2013, which was representative of spring high-flows. Therefore, the flow condition for the calibration model was not used and a synthetic August low-flow condition was developed. Since the input of monitored flows on August 12-13, 2013 would require a re-calibration of the hydrology, all flow inflows and outflows were reduced by 79 percent to preserve the water balance developed during model calibration. This 79 percent reduction factor was based upon a comparison of monitored flows from June 26-27, 2013 and August 12-13, 2013. The 79 percent reductions were applied to tributary and headwaters boundary conditions inflows and groundwater inflow/outflows.

4.1.1.4 Irrigation Withdrawals

The August 12-13 irrigation withdrawals provided by DEQ were used to develop the baseline condition. Refer to Section A-8 of Appendix A for a discussion of irrigation withdrawal data. The baseline was developed using August because considerably less water is diverted for irrigation in September.

4.1.1.5 Baseline Scenario Results

The modeled water temperatures for the baseline scenario are shown below in **Figure 14**. The simulated maximum temperatures ranged from 58.0° F to 81.7° F. Simulated maximum daily temperatures exceeded 80 F from the mouth upstream to river mile 0.17, from river miles 2.59 to 3.52 (segments upstream of logger MC-T2), and from river miles 4.64 to 4.83 (just upstream of logger MC-T3). The warmest temperature (81.7° F) occurred at river mile 2.96, just upstream of logger MC-T2).

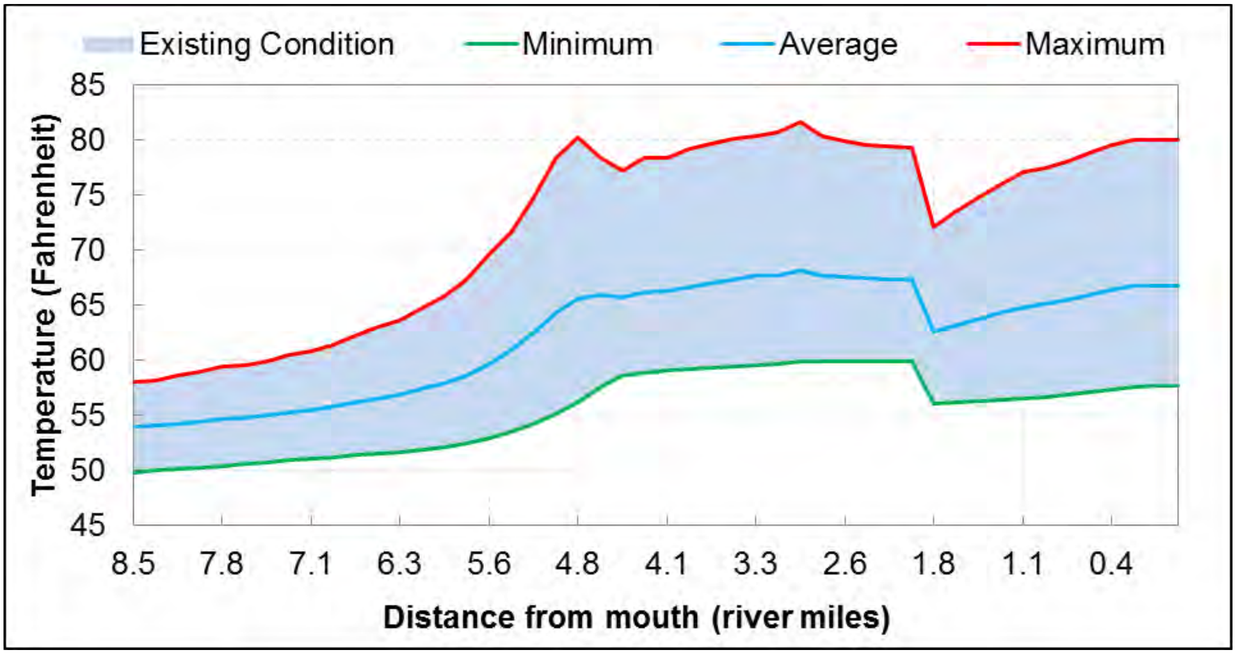


Figure 14. Simulated water temperature for baseline condition (August 15, 2013).

4.2 Water Use Scenario

Irrigation (or other water withdrawals) deplete the volume of water in the stream and reduce in-stream volumetric heat capacity. Theoretically the reduced stream water volume heats up more quickly (and also cools more quickly), given the same amount of thermal input. A single water use scenario was modeled to evaluate the potential benefits associated with application of water use best management practices (scenario 2).

In this scenario, the point sources abstractions representing the withdrawals (see **Appendix A** and **Table 4** for the withdrawals) in the QUAL2K model are reduced by 15 percent (NRCS 1997). The water previously withdrawn (2.07 cfs) is now allowed to flow down Mill Creek; flow in Mill Creek was 2.52 cfs at logger MC-T1, near the mouth, on August 13, 2013. This scenario is intended to represent application of conservation practices relative to water use.

The water temperatures under this scenario generally exhibited decreases along the middle segments of Mill Creek that reflect the locations of the irrigation withdrawals (**Figure 15**). The maximum change in the maximum daily water temperature is representative of the worst case conditions. A maximum change in the maximum daily water temperature of 8.1° F from the existing condition was observed at RM 4.8. Cooler temperatures at RM 4.8 may be due to the upstream irrigation withdrawals' reductions that allowed for more water in Mill Creek.

The changes in maximum daily temperatures from the water use scenario, as compared to the baseline, ranged from 8.1° F cooler to 0.7° F warmer with an average of 0.7° F cooler. The temperature difference of the daily maximums was 0.5° F or greater for about three-fifths of the stream.

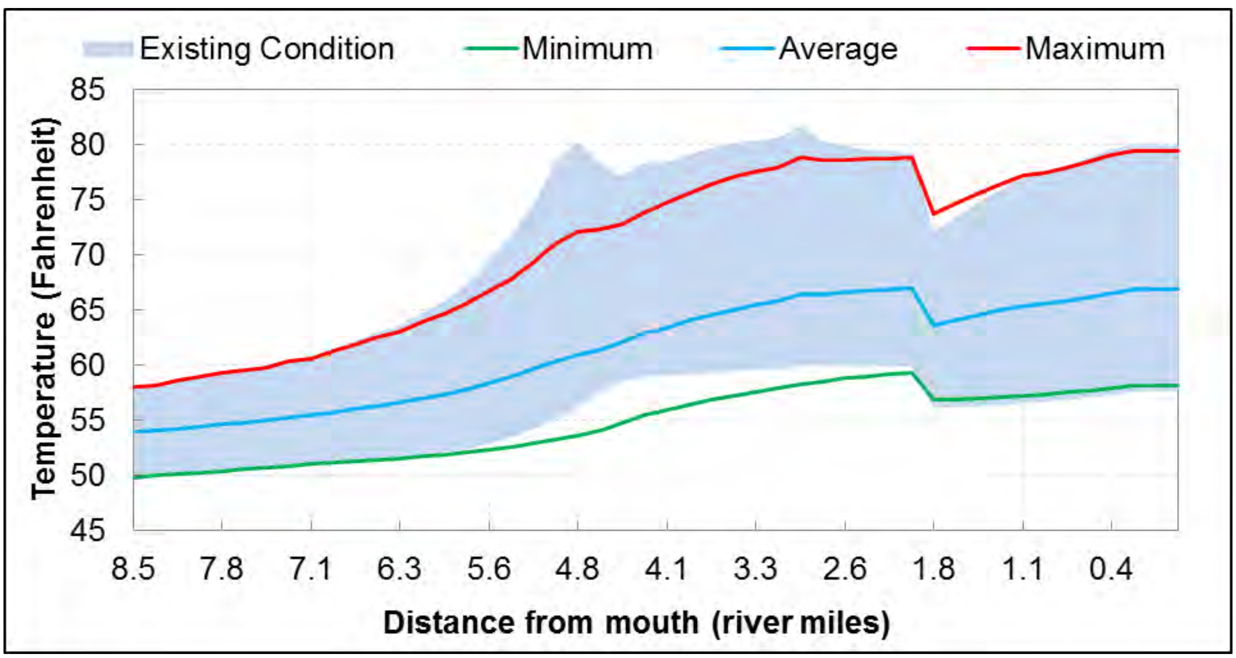


Figure 15. Simulated water temperatures for the baseline (scenario 1) and 15-percent withdrawal reduction (scenario 2).

4.3 Shade Scenario

The riparian plant community blocks incoming solar radiation, which directly reduces the heat load to the stream. A single shade scenario was modeled to evaluate the potential benefits associated with increased shade along certain segments of Mill Creek.

An evaluation of shading using the Solar Pathfinder™ measurements, Shade model results, GIS, and aerial imagery and incorporating DEQ's input resulted in the following conclusions:

1. Vegetation along Mill Creek above RM 7.5 (i.e., above logger MC-T6) is likely at potential and there is very little opportunity to improve shade. Therefore, the segments upstream of logger MC-T6 will not be altered for the shade scenario.
2. Vegetation communities along Mill Creek from RMs 7.5 to 4.5 (i.e., just upstream of logger MC-T5 to logger MC-T3) are dominated by mixed coniferous/deciduous forest and are impacted by encroachment from residential developments and agriculture. There is opportunity to convert some of the encroached areas to mixed coniferous/deciduous trees. Therefore, shade along this segment will be improved to a reference condition, which is conservatively defined as the segment at logger MC-T3 that is forested and at potential.
3. Downstream of RM 4.5 (i.e., from logger MC-T3 to the mouth), Mill Creek flows through predominantly low-density residential lands. There is opportunity to improve the vegetation communities in these areas. Therefore, shade along this segment will be improved to a reference condition, which is conservatively defined as the segment at logger MC-T2 that is composed of shrubs in a 50-foot to 100-foot buffer, when the existing average daily effective shade of a given segment is less than 50 percent.

The Mill Creek QUAL2K model was re-run using the altered shade inputs, based upon the findings presented above (**Table 11**); refer to **Appendix B** for additional information regarding the shade scenario. This scenario is intended to represent application of conservation practices relative to shade although it is important to note that even in natural forested conditions, there are still openings in the canopy and some areas without vegetation. Hence this is likely an upper limit to what plausibly could occur from vegetation management practices.

Table 11. Average daily shade inputs per model segment

Segment	Existing condition (scenario 1)	Shade (scenario 3)
MC-T6 to MC-T5	68%	69%
MC-T5 to MC-T4	61%	61%
MC-T4 to MC-T3	52%	59%
MC-T3 to MC-T2	39%	47%
MC-T2 to Sheafman Creek	36%	46%
Sheafman Creek to MC-T1	39%	48%
MC-T1 to mouth	53%	55%

Note: For each segment, the effective shade per hour was averaged across 15 meter intervals for each hour from 5:00 am through 9:59 pm (yielding average effective shade per hour per model segment) and then averaged across daylight hours (yielding average effective shade per day per model segment.

Water temperatures in Mill Creek downstream of logger MC-T4 decreased (**Figure 16**). A maximum change in the maximum daily water temperature of 3.7° F from the baseline was observed at RM 4.8. Shading increased between RMs 4.73 to 4.92, which had lower levels of shading that segments immediately upstream and downstream of this segment. The larger change (to cooler temperatures) at RM 4.8 was likely do to the increased shading. The difference in the daily maximum water temperature between the baseline and shade scenario was greater than 0.5° F from RM 5.2 to the mouth. It is important to note the caveats previously stated: that this is likely the largest improvement that could be observed through vegetation management practices.

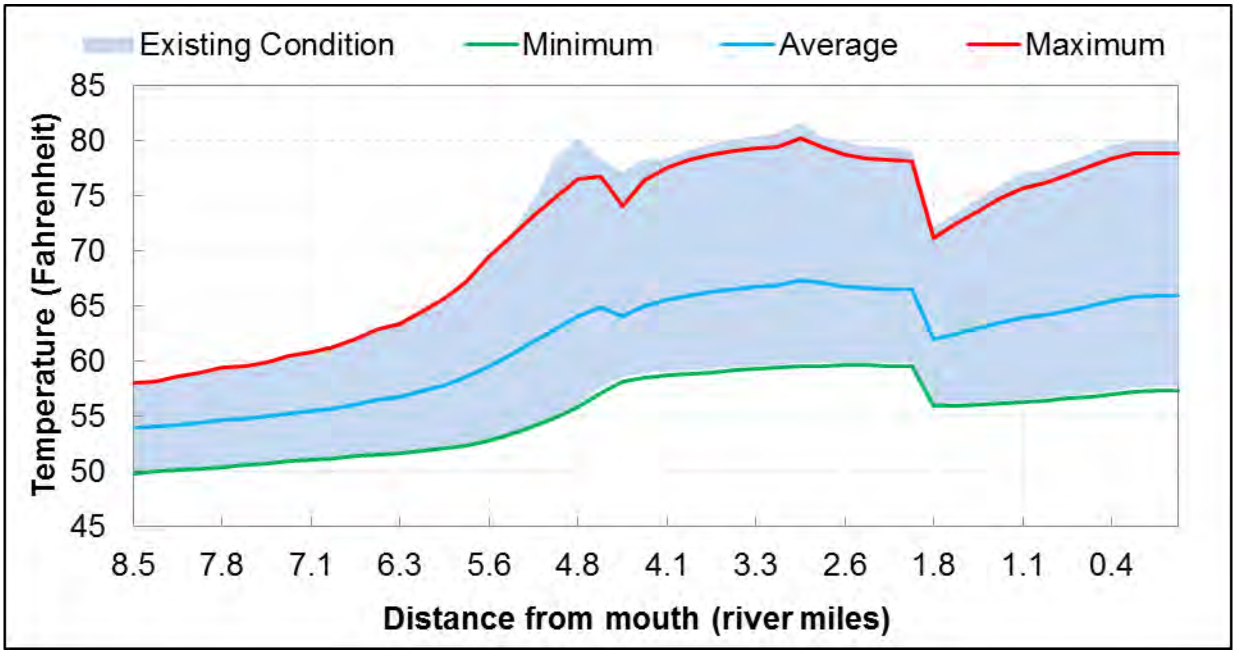


Figure 16. Simulated water temperatures for the baseline (scenario 1) and increased shade (scenario 3).

4.4 Improved Flow and Shade Scenario

The improved flow and shade scenario (scenario 4) combines the potential benefits associated with a 15 percent reduction in water withdrawals (scenario 2) with increases shade to reference levels along certain segments (scenario 3).

Simulated maximum daily temperatures ranged from 58.0° to 65.5° from rivermiles 8.5 to 5.6 and ranged from 66.7° to 78.8° from rivermiles 5.6 to the mouth. As per the temperature standard discussed in **Section 2.2**, anthropogenic activities may increase the in-stream temperatures by 1.0° F for the segment from rivermiles 8.5 to 5.6 and by 0.5° F for the segment from rivermile 5.6 to the mouth.

In this scenario, water temperatures in Mill Creek decrease throughout much of the system (**Figure 17** and **Figure 18**). A maximum change in the maximum daily water temperature of 10.3° F from the baseline was observed at RM 4.8. The changes in maximum daily temperatures from the improved flow and shade scenario, as compared to the baseline, ranged from 10.3° F cooler to 0.5° F warmer with an average of 2.5° F cooler. The difference in the daily maximum water temperature between the baseline and the improved flow and shade scenario was greater than 1.0° F in most simulated segments of Mill Creek, which confirms that Mill Creek is impaired by elevated in-stream water temperatures.

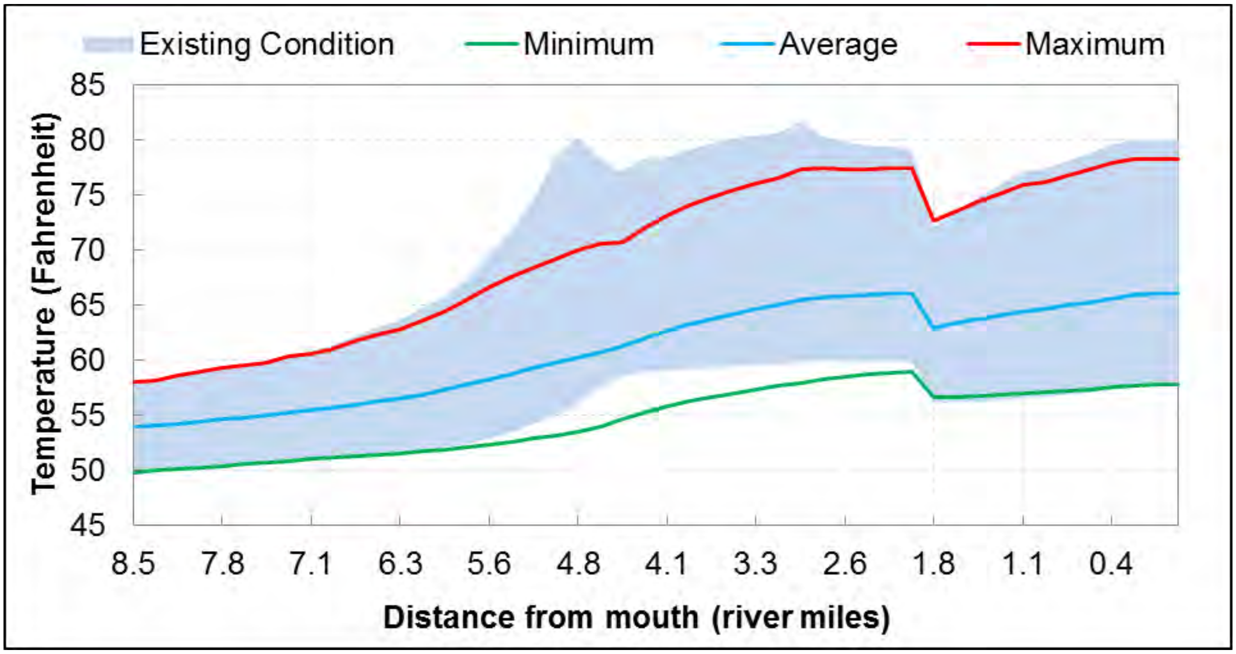


Figure 17. Simulated water temperature for the baseline (scenario 1) and the improved flow and shade scenario (scenario 4).

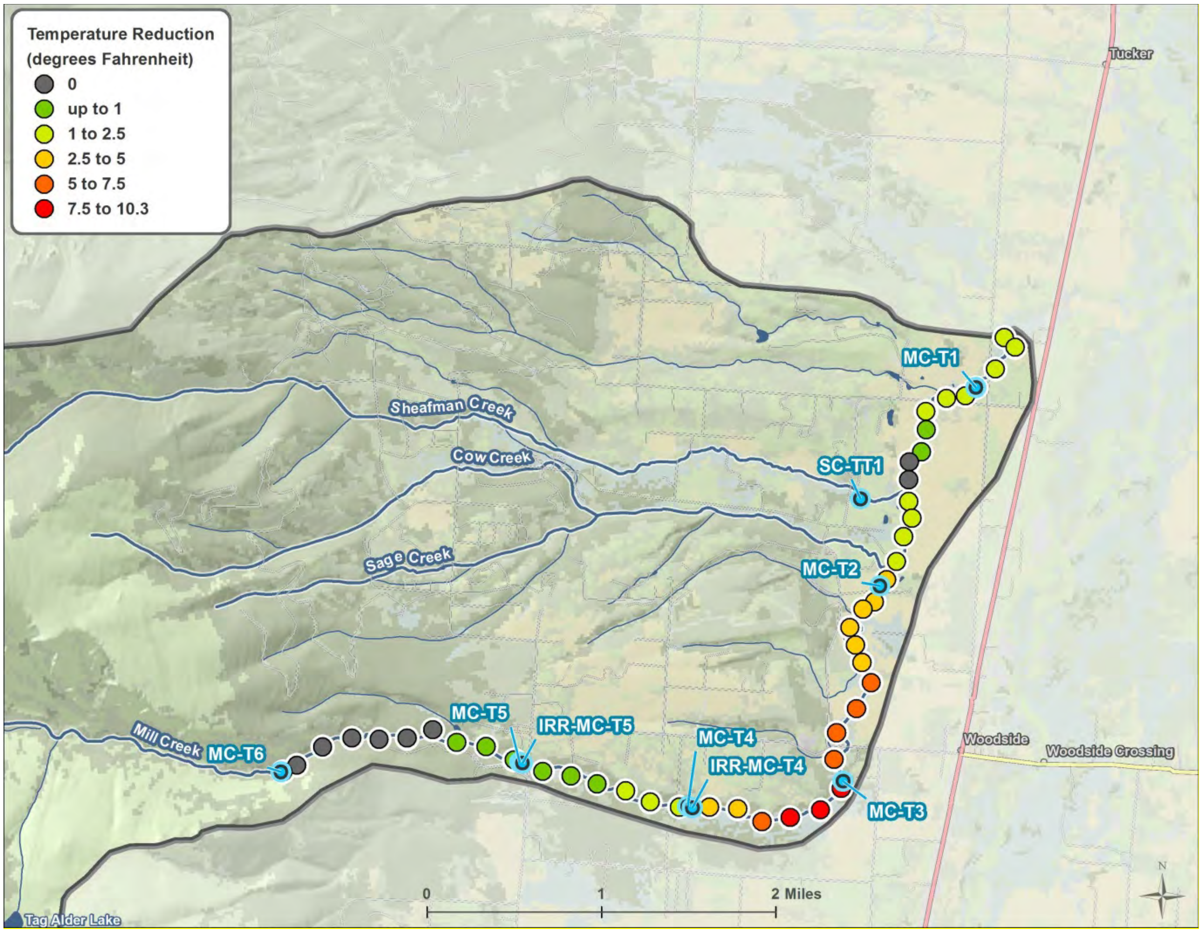


Figure 18. In-stream temperature difference from the baseline (scenario 1) to the improved flow and shade scenario (scenario 4).

5 Assumptions and Uncertainty

As with any model, the QUAL2K model is subject to uncertainty. The major sources of model uncertainty include the mathematical formulation, input and boundary conditions data uncertainty, calibration data uncertainty, and parameter specification (Tetra Tech 2012). As discussed in the quality assurance project plan (Tetra Tech 2012), the QUAL2K model code has a long history of testing and application, so outright errors in the coding of the temperature model are unlikely. The Shade Model has also been widely used so a similar sentiment exists. A potentially significant amount of the overall prediction uncertainty is due to uncertainty in the observed data used for model setup, calibration, and validation, and assumptions used in the scenario analysis itself.

5.1 Uncertainty with Model Development

With respect to input data (including instantaneous flow, continuous temperature, channel geometry, hourly weather, spatial data or other secondary data), weather and spatial data were obtained from other government agencies and were found to be in reasonable ranges, and are therefore assumed to be accurate. Uncertainty was minimized for the use of other these data following procedures described in the quality assurance project plant (Tetra Tech 2012).

In addition, assumptions regarding how these data are used during model development contain uncertainty. The following key assumptions were used during Mill Creek QUAL2K model development:

- Mill Creek can be divided into distinct segments, each considered homogeneous for shade, flow, and channel geometry characteristics. Monitoring sites at discrete locations were selected to be representative of segments of Mill Creek.
- Spatial variability of velocity and depth (e.g. stream meander and hyporheic flow paths) are represented through exponents and coefficients of the selected rating curves for each segment.
- Weather conditions at the Smith Creek RAWS are representative of local weather conditions along Mill Creek.
- Shade Model results are representative of riparian shading along segments of Mill Creek. Shade Model development relied upon the following three estimations of riparian vegetation characteristics:
    - Riparian vegetation communities were identified from visual interpretation of aerial imagery.
    - Tree height and percent overhang were estimated from other similar studies conducted outside of the Mill Creek watershed.
    - Vegetation density was estimated using the National Land Cover Dataset (Multi-Resolution Land Characteristics Consortium 2001) and best professional judgment.

  Shade Model results were corroborated with field measured Solar Pathfinder™ results and were found to be reasonable. The average absolute mean error is 8 percent. (i.e., the average error from the Shade Model output and Solar Pathfinder™ measurements was 5 percent daily average shade).

- Simulated diffuse flow rates are representative of groundwater inflow/outflow, irrigation diversion, irrigation return flow, and other sources of inflow and outflow not explicitly modeled. Diffuse flow rates were estimated using flow mass balance equations for each model reach.

5.2 Uncertainty with Scenario Development

The increased shade scenario (scenario 3) assumes that the shade from vegetation along the reference segment is achievable in the segments with anthropogenically diminished shade. The increased shade scenario (scenario 3) represents the feasible temperature benefit that could be achieved over a time period long enough to allow vegetation to mature (tens of years). Therefore, temperature improvements in the short term are likely to be less than those identified in the scenario 3 results. Natural events such as flood and fire may also alter the maximum potential for the riparian vegetation or shift the time needed to achieve the maximum potential. This condition may not be achievable for all areas due to the coarse scaled used to identify the current and potential shade conditions and the fact that even natural systems tend to have spatial patchiness of tree canopy cover.

6 Model Use and Limitations

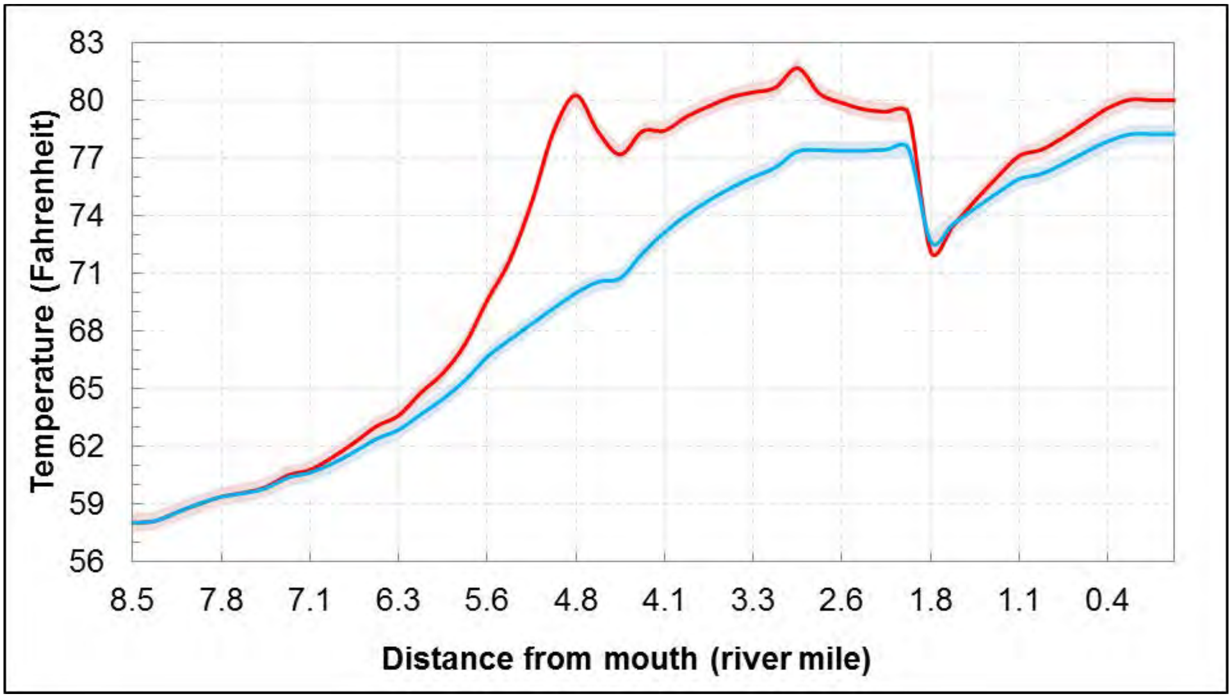
The model is only valid for summertime, warm-weather conditions and should not be used to evaluate high flow or other conditions. As described above, steps were taken to minimize uncertainty as much as possible. Despite the uncertainty, the model adequately addresses the primary questions:

1. What is the sensitivity of in-stream temperature to the following thermal mechanisms and stressors: shade, irrigation withdrawal and return?
2. What levels of reductions in controllable stressors are needed to achieve temperature standards?

The first question can be answered using the calibrated and validated QUAL2K model for Mill Creek. As previously discussed, Mill Creek is sensitive to shade and flow.

The second question can be answered using the calibrated QUAL2K model and the scenarios developed to assess water use and shade. In this instance, increasing riparian shading will decrease in-stream temperatures significantly (>3°F for maximum); however, there is uncertainty in the magnitude of temperature reduction as estimates are contingent on what was considered to be reference shade. Additionally, decreasing water diverted for irrigation will decrease in-stream temperatures significantly (>8°F for maximum). While a "good" model calibration was achieved, the overall Absolute Mean Error (AME) for the maximum daily temperature was 0.5° F.

Figure 19 graphically summarizes the comparison between the baseline condition and improved flow and shade scenario. Based on these results, and the fact that Montana's temperature standard as applied to Mill Creek is limited to an increase of 1° F, it is clear that impacts are occurring to the stream and that the mechanism to address these temperature concerns will be the mitigation of stream shade through plantings or riparian enhancement and reduction of irrigation withdrawals to allow more water to flow down the stream. Continued monitoring should be done in conjunction with these activities to ensure that they are of benefit, in particular given that model results are uncertain as described previously.



Note: The baseline (scenario 1) is the red line and the improved flow and shade scenario (scenario 4) is the blue line. The shaded areas are plus or minus the average AME (0.5° F).

Figure 19. Simulated daily maximum water temperatures from the baseline (red; scenario 1) and improved flow and shade scenario (blue; scenario 4).

7 Conclusions

The scenarios resulted in water temperatures reductions as much as 10.3° F.

A flow scenario representing irrigation efficiency was evaluated and the locations that showed the greatest potential for improvement were localized to areas just downstream of the existing withdrawals. The 15-percent reductions in water use resulted in appreciable reductions to the temperature in the middle segments of Mill Creek. The largest reductions (range: 4.5° F to 8.1° F) occurred from RMs 4.1 to 5.2.

The improved shade scenario showed smaller temperature reductions than the water use scenario; however, the improved shade scenario showed reductions along more length of stream than the water use scenario. Reductions of 0.5° F occurred from RM 5.2 to the mouth.

The improved flow and shade scenario that combined the potential benefits associated with a 15 percent reduction in water withdrawals (scenario 2) with increased shading based upon reference levels (scenario 3) to represent application of conservation practices relative to the temperature impairment was also simulated. This scenario resulted in overall reductions along the most of the stream, which ranged from <0.1° F to 10.3° F (Table 12), except for the segment from RMs 1.7 to 1.9. The scenario shows that reductions in water temperatures are achievable throughout the stream, but reductions of 0.5° F are achievable from RMs 6.5 to 6.1 and reductions of 1.0 F are achievable from RM 6.1 to the mouth (except from RMs1.3 to 1.9); refer back to **Figure 18** for a map of potential temperature reductions. The greatest potential improvement (i.e., reduction) occurs between RMs 2.8 and 5.4 (4.1° F to 10.3° F improvement) (**Figure 21**). Above logger MC-T6 (about RM 8.5), the vegetation communities are at potential and no shade improvements were simulated. Efforts should be spent on re-vegetation in these areas most amenable to this type of restoration activity in the lower reaches of Mill Creek.

Table 12. In-stream temperature difference from the baseline scenario

Scenario ID	Scenario name	Daily maximum			Daily average		
		Range of change [a]	Average change [b]	Median change [c]	Range of change [a]	Average change [b]	Median change [c]
2	Water Use	-8.1 to +1.6	-1.6	-0.6	-3.8 to +0.7	-0.7	-0.1
3	Shade	-3.7 to 0	-0.9	-1.1	-0.4 to 0	-0.2	-0.2
4	Improved Flow and Shade	-10.3 to +0.5	-2.5	-1.8	-3.9 to +0.5	-0.8	-0.1

Notes

Results are reported in degrees Fahrenheit. Negative values represent scenario results that were cooler than the Baseline scenario while positive values represent scenario results that were warmer than the baseline scenario.

a. The range of temperature changes along Mill Creek as compared with the baseline scenario.

b. The distance-weighted average temperature change along Mill Creek as compared with the baseline scenario.

c. The distance-weighted median temperature change along Mill Creek as compared with the baseline scenario.

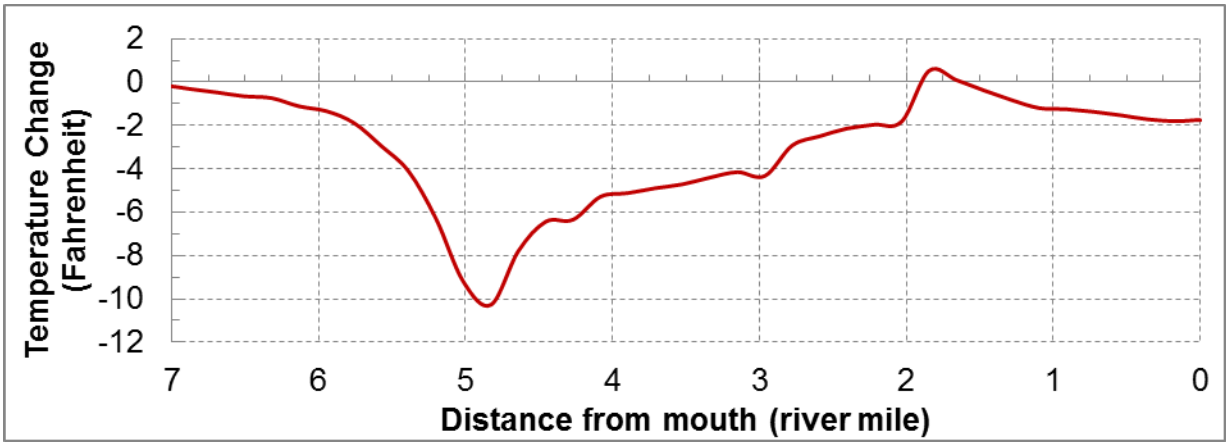


Figure 20. Simulated water temperature reduction from the existing condition (scenario 1) to the improved flow and shade scenario (scenario 4).

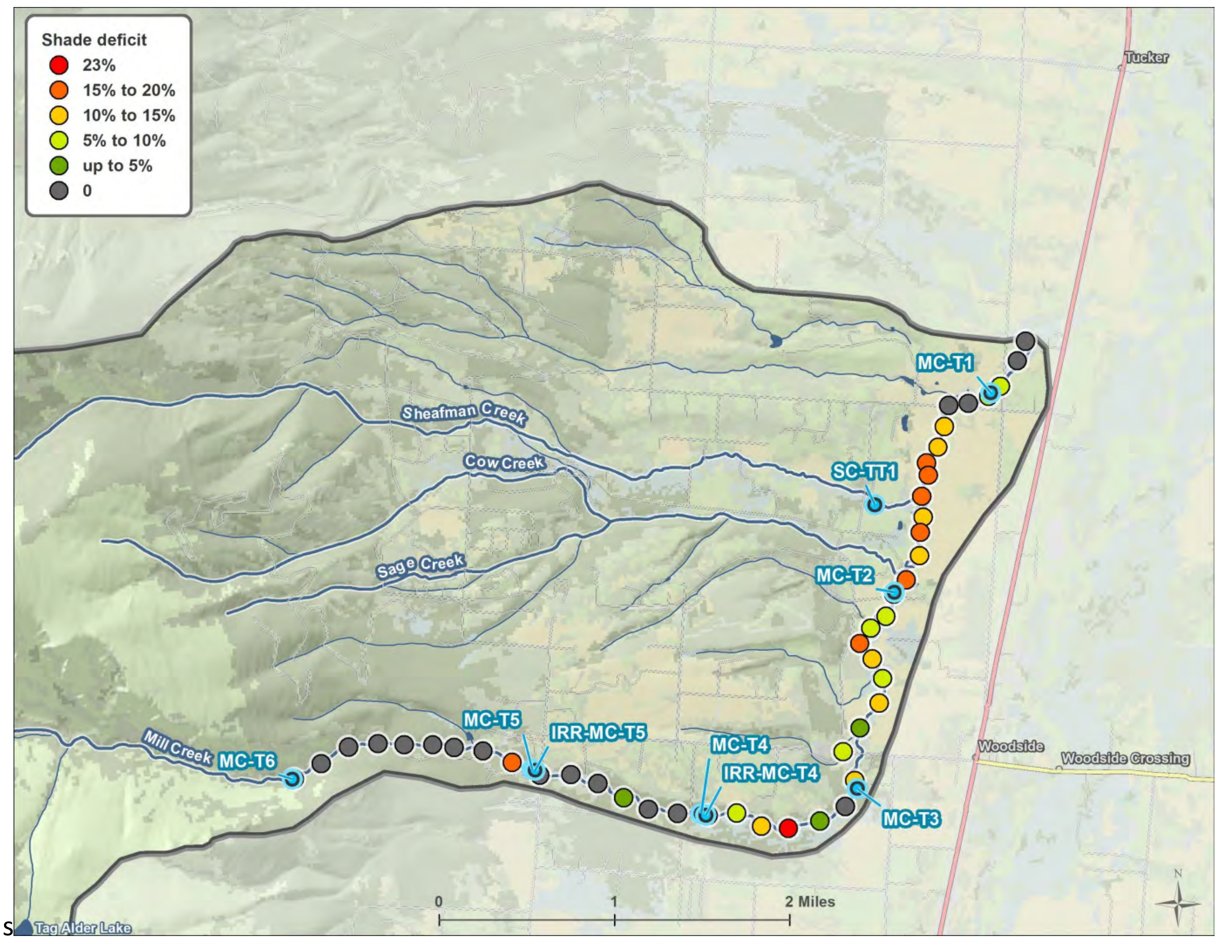


Figure 21. Shade deficit of the existing condition (scenario 1) from the improved flow and shade scenario (scenario 4).

8 References

Chapra, S.C., 1997. Surface water quality modeling. McGraw-Hill Companies, Inc.

Chapra, S., G. Pelletier, and H. Tao. 2008. QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Version 2.11: Documentation and User's Manual. Tufts University, Civil and Environmental Engineering Department, Medford, MA.

Chow, V.T., D.R. Maidment, and L.W. Mays, 1988. Applied Hydrology. McGraw-Hill, New York. 592 pp.

DEQ (Montana Department of Environmental Quality). 2013. Water Quality Assessment Database. Montana Department of Environmental Quality, Clean Water Act Information Center. <http://cwaic.mt.gov/query.aspx>. Accessed June 5, 2013.

Multi-Resolution Land Characteristics Consortium. 2006. *National Land Cover Dataset 2006*. <http://www.mrlc.gov/nlcd2006.php>. Accessed June 28, 2012.

NRCS (Natural Resources Conservation Service). 1997. National Engineering Handbook Irrigation Guide, Part 652. United States Department of Agriculture, Natural Resources Conservation Service. Washington, D.C.

Poole, G.C., Risley, J. and M. Hicks. 2001. Issue Paper 3 – Spatial and Temporal Patterns of Stream Temperature (Revised). United States Environmental Protection Agency. EPA-910-D-01-003.

Tetra Tech. 2012. *Quality Assurance Project Plan for Montana TMDL Support: Temperature Modeling*. QAPP 303 Revision 0, March 28, 2012. Prepared for the U.S. Environmental Protection Agency, by Tetra Tech, Inc., Cleveland, OH.

Appendix A.

Factors Potentially Influencing Stream Temperature

in Mill Creek

Contents

Tables

Figures

A-1. Introduction

Stream temperature regimes are influenced by processes that are external to the stream as well as processes that occur within the stream and its associated riparian zone (Poole et. al., 2001). Examples of factors external to the stream that can affect in-stream water temperatures include: topographic shade, land use/land cover (e.g., vegetation and the shading it provides, impervious surfaces), solar angle, meteorological conditions (e.g., precipitation, air temperature, cloud cover, relative humidity), groundwater exchange and temperature, and tributary inflow temperatures and volumes. The shape of the channel can also affect the temperature—wide shallow channels are more easily heated and cooled than deep, narrow channels. The amount of water in the stream is another factor influencing stream temperature regimes. Streams that carry large amounts of water resist heating and cooling, whereas temperature in small streams (or reduced flows) can be changed more easily.

The following factors that may have an influence on stream temperatures in Mill Creek are discussed below:

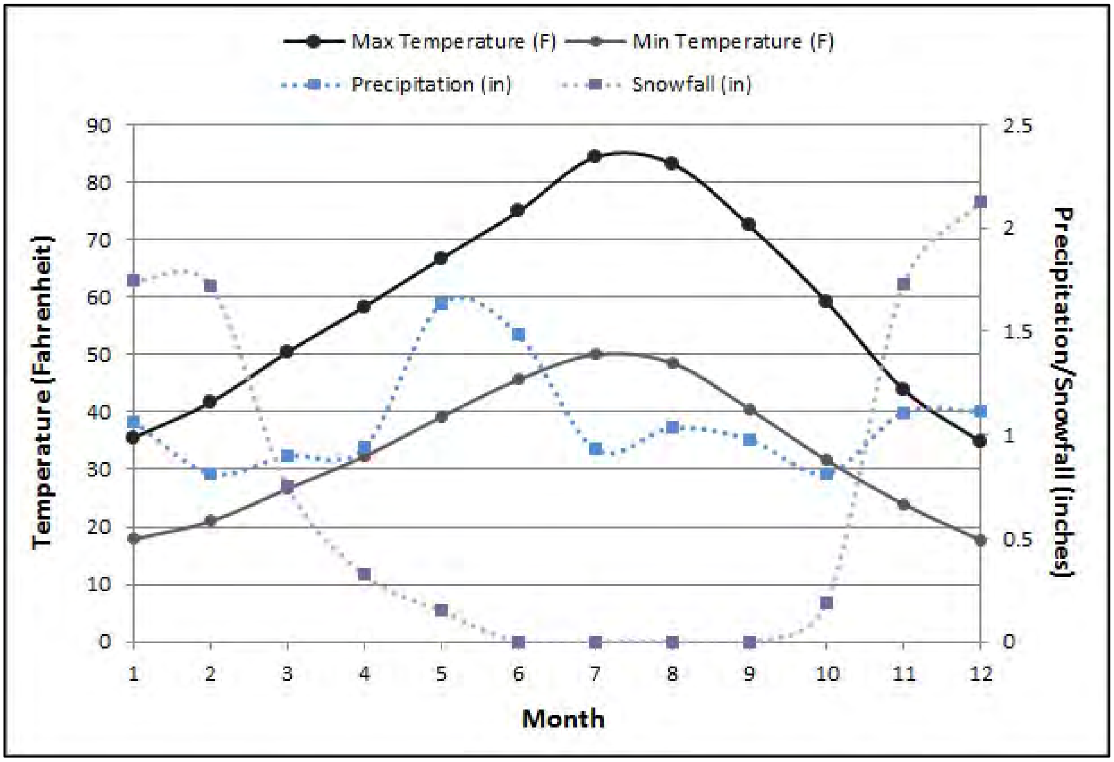
- Local/regional climate
- Land ownership
- Land use
- Riparian vegetation
- Shade
- Hydrology
- Point sources

A-2. Climate

The nearest weather station to the Mill Creek watershed is located in the city of Hamilton, Montana, 6.7 miles to the south of the mouth of Mill Creek. (National Weather Service station 243885). Average annual precipitation is 12.8 inches with the greatest amounts falling in May and June (**Figure A-2**; National Climate Data Center 2012). Average maximum temperatures occur in July and August and are 84.3° F and 83.1° F, respectively.

It should be noted that the Hamilton weather station is located at an elevation of 3,593 feet above MSL, compared to Mill Creek that ranges in elevation from approximately 3,400 to 8,800 feet above MSL.

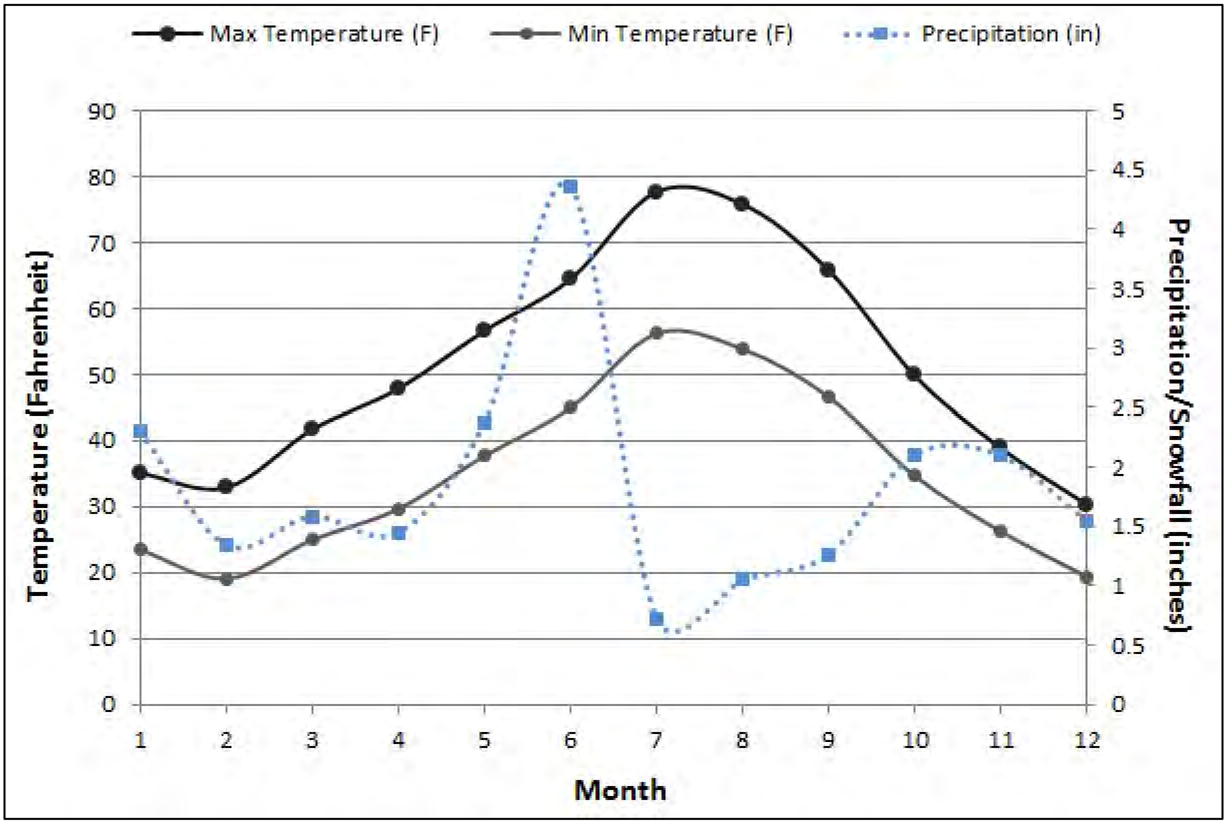
Figure A-1. Mill Creek watershed.



Source: GHCN-D Monthly Summaries from 1970 to 2012 at Station 243885 (National Climactic Data Center 2013).

Figure A-2. Monthly average temperatures and precipitation at Hamilton, Montana.

The Hamilton station only has hourly air temperature data and does not have additional hourly datasets necessary for QUAL2K modeling. The Smith Creek RAWS records hourly air temperature, dew point temperature, wind speed and solar radiation and these data were used to develop the QUAL2K model. The Smith Creek RAWS is located 7.3 miles to the north of the mouth of Mill Creek at an elevation of 5,650 feet above MSL, compared to Mill Creek that ranges in elevation from approximately 3,400 to 8,800 feet above MSL.

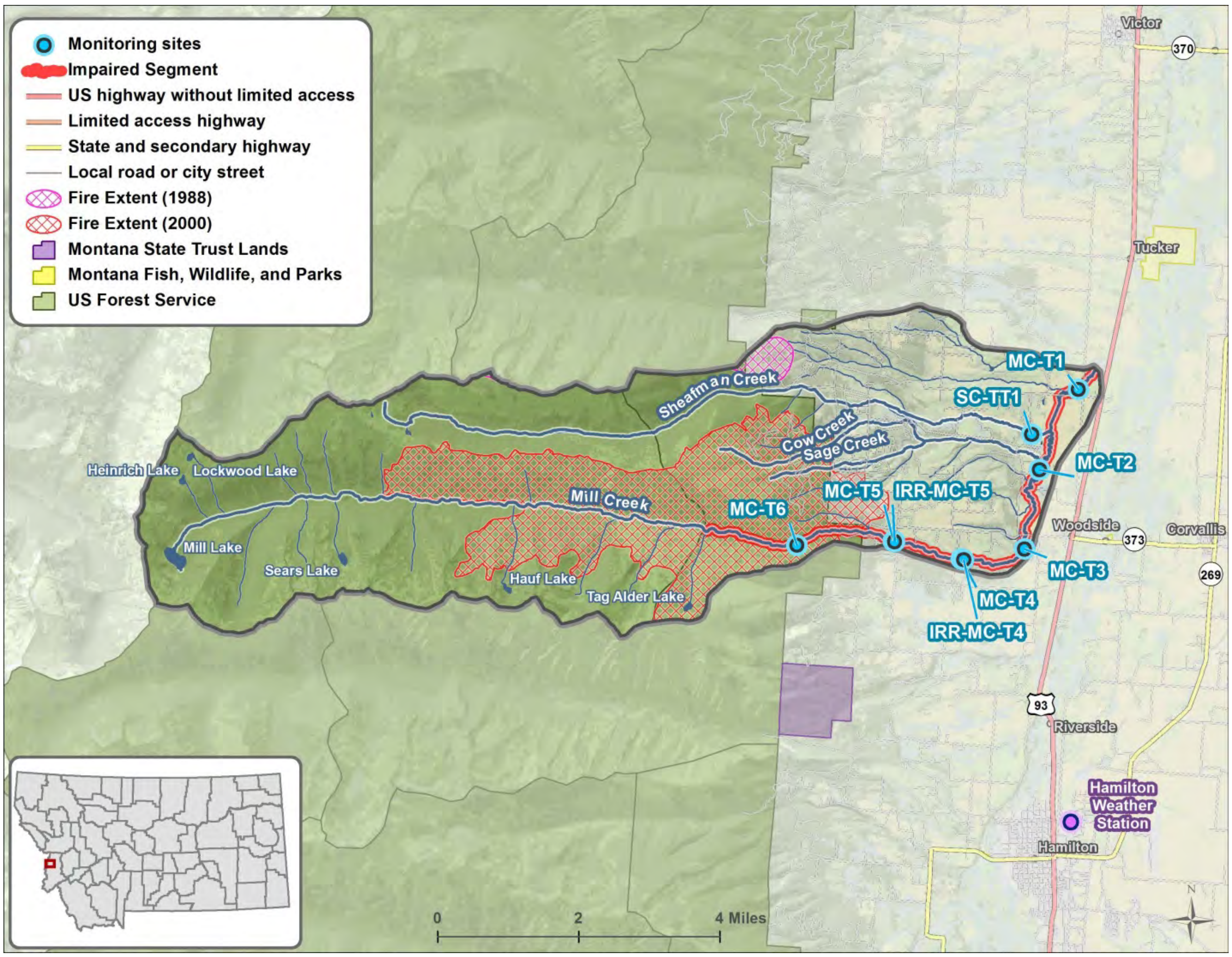


Source: RAWS weather data from 2001 to 2013 at Smith Creek station (Western Regional Climate Center, 2014).

Figure A-3. Monthly average temperatures and precipitation at Smith Creek RAWS.

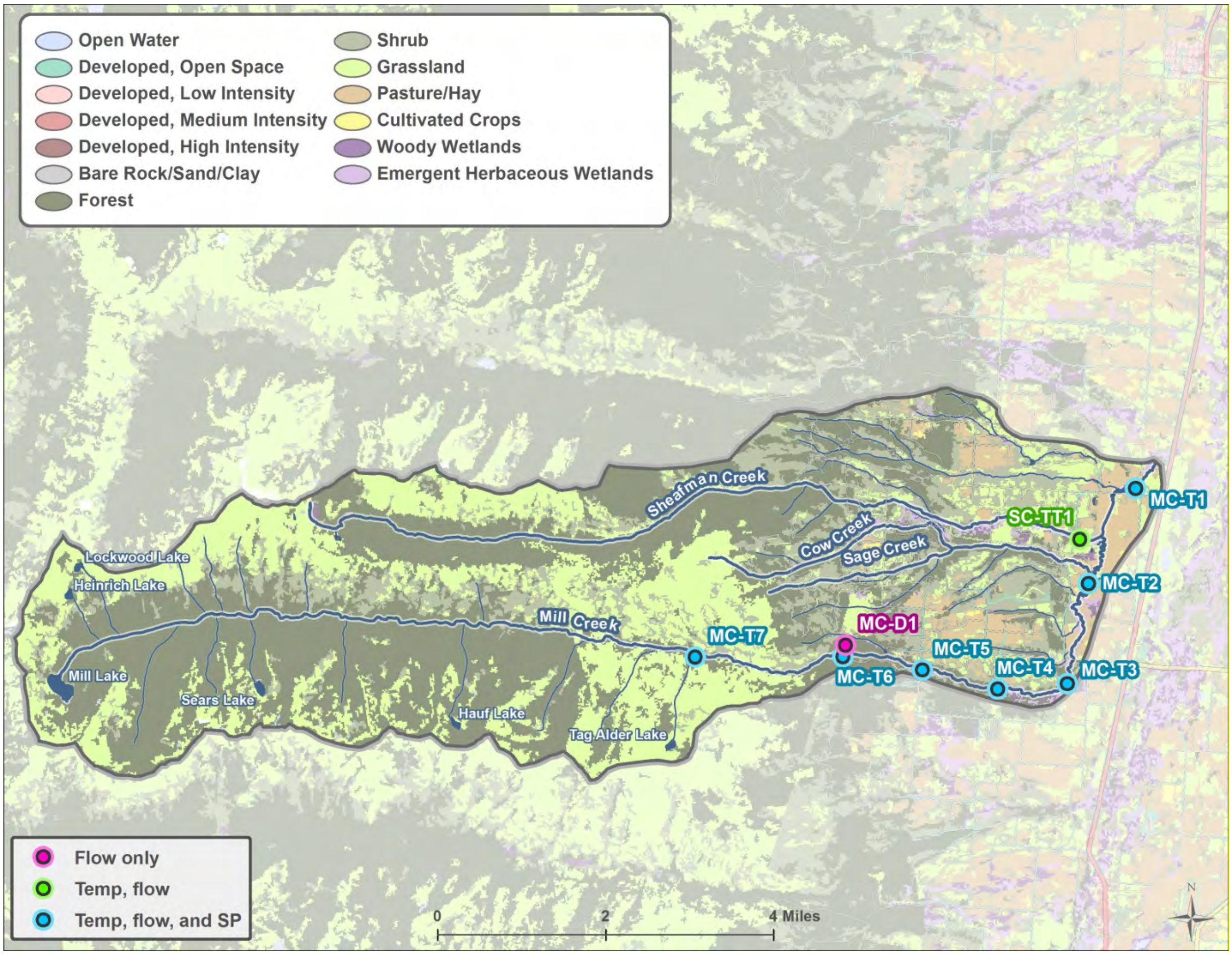
A-3. Land Ownership and Land Use

The upper two-thirds of the Mill Creek watershed is owned by the U.S. Forest Service and is predominantly forested (**Figure A-4** and **Figure A-5**). Two fires occurred in recent history within the watershed (U.S. Forest Service 2008). The earliest, in 1988, covered 240 acres, or approximately 1% of the watershed (**Figure A-4**). More recently, in 2000, a fire covering 6,551 acres (26% of the area) occurred in the middle section of the watershed (**Figure A-4**). The lower reaches of the watershed are privately held and transition into a mosaic of small acerage agricultural lands and low density residential.



Source of land ownership: NRIS 2012.

Figure A-4. Land ownership in the Mill Creek watershed.



Source of land cover: 2006 National Land Cover Dataset (MRLC, 2006).

Figure A-5. Land cover and land use in the Mill Creek watershed.

A-4. Existing Riparian Vegetation

A comprehensive inventory and assessment of the current riparian vegetation communities adjacent to Mill Creek was not conducted as part of this project. Riparian vegetation communities, however, were qualitatively assessed, and the height and density of the dominant vegetation were measured at the six shade monitoring sites in August 2013. A summary of the observed characteristics of the vegetation communities is provided in **Table A-1**.

The impaired reach of Mill Creek is 8.7 miles in length. The upper 2.5 miles flow through the Bitterroot National Forest in an area that was burned in 2000. The riparian corridor in this area, however, is largely un-impacted by the fire and dominated by conifer forest with an alder understory. This vegetation appears to be at its natural potential.

Downstream, Mill Creek flows out of the mountains and onto private property until discharging into the Bitterroot River. Mixed coniferous/deciduous forests and shrub communities are more common in the riparian corridor in this lower reach. Throughout much of its length in this lower reach, the riparian corridor has been encroached upon, to varying degrees, by agricultural and residential land uses. Sites MC-T1 and MC-T5 (refer to **Figure A-8** for site locations) are examples of areas not meeting their potential due to encroachment by residential and agricultural activities. Where undisturbed buffers have been maintained (e.g., sites MC-T2, MC-T3, and MC-T4), the vegetation appears to be largely at potential.

Table A-1. Observed characteristics of the Mill Creek riparian vegetation community

Station ID	Site Name	Dominant Vegetation	Vegetation at potential?	Average Vegetative Density (percent shade)[a]	Dominant Vegetation Height (feet)[a]	Dominant Vegetation Overhang (feet)[a]	Description
MC-T1	Mill Creek near mouth	Shrub	N	62	17.5	7	This site is located in a rural residential area. An approximate 25 ft. band of shrubs (willow, alder, and dogwood) borders the stream at this location, with mowed lawns or agricultural fields adjacent on the landward side.
MC-T2	Mill Creek near Shadow Mountain Road	Shrub	Y	92	17.5	1.5	Wetland shrub dominated riparian corridor (willows and alders) with an occasional cottonwood. Point bars dominated by reed canary grass.
MC-T3	Mill Creek near Dutch Hill Rd	Tree (mixed decid/conifer)	Y	***75***	63	3.5	Forested site dominated by cottonwood and pine.
MC-T4	Mill Creek near Pheasant Run Rd	Tree (mixed decid/conifer)	Y	84	62		Mixed deciduous/coniferous vegetation community (cottonwood, aspen, pine, spruce).
MC-T5	Mill Creek near Bowman Rd	Tree (mixed decid/conifer)	N	***25-75***	46	10	The right bank is dominated by cottonwood and alder. The left bank has been partially cleared with occasional pine/spruce remaining.
MC-T6	Mill Creek headwaters	Tree (conifer)	Y	75	80		This site is located on the edge of a burned area. The riparian corridor, however, has been largely unaffected and is dominated by pine/spruce with an occasional cottonwood with an alder dominated understory.

Notes
Bold/italicized blue values are based on visual estimate (no measurements available).
a: Average of field measurements.

Vegetation communities between the shade monitoring sites were visually characterized based on aerial imagery (GoogleEarth™ 2013) with qualitative field verification conducted during temperature logger deployment and retrieval. Observed vegetative communities within 150 feet of the stream centerline were classified as trees, shrubs, herbaceous. Areas without vegetation, such as bare earth or roads, were also identified. Trees were further divided into the following classes based on percent canopy cover derived from the 2001 National Land Cover Dataset (**Figure A-6**):

- High density (75 to 100 percent cover)
- Medium density (51 to 74 percent cover)
- Low density (25 to 50 percent cover)
- Sparse density (less than 24 percent cover)

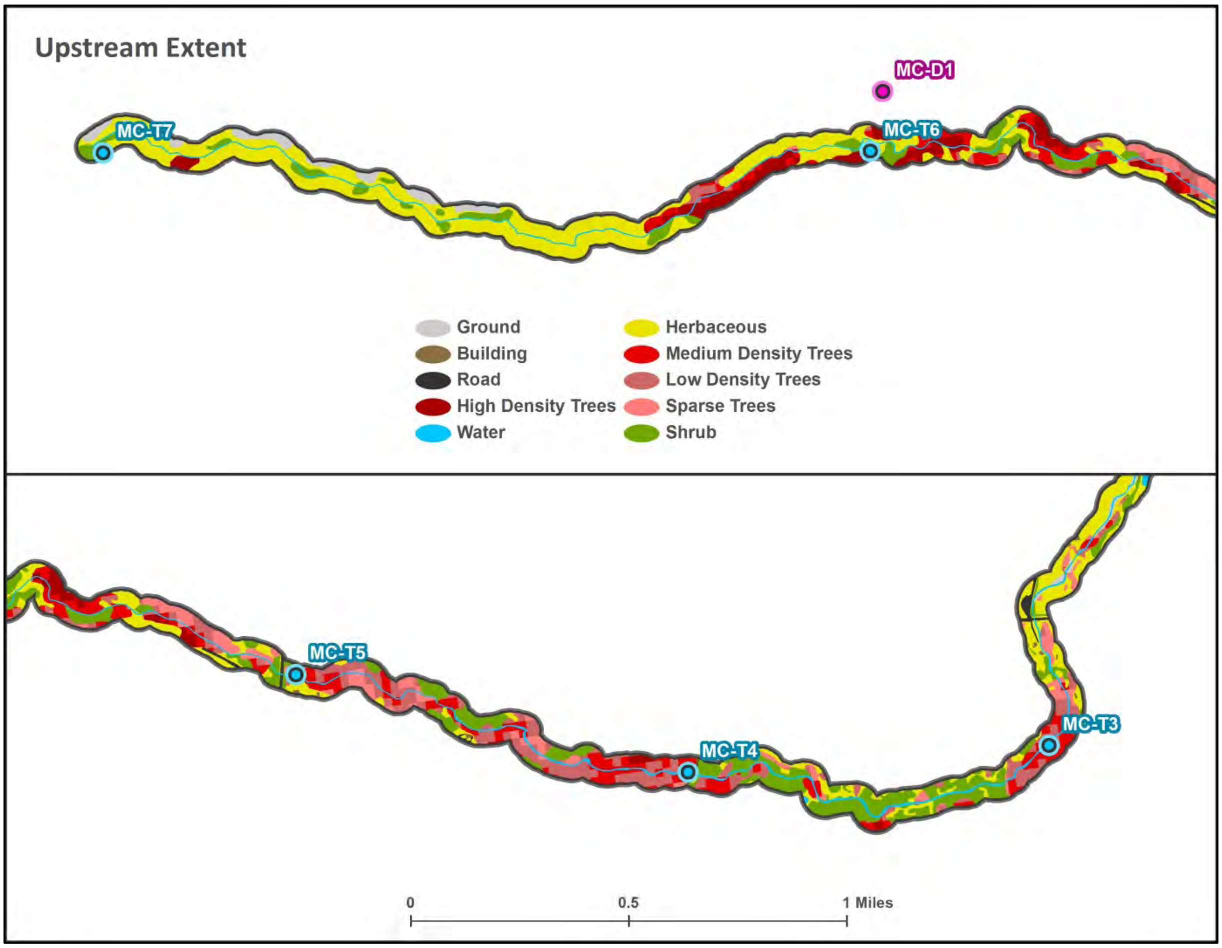


Figure A-6. Vegetation mapping example for Mill Creek in the upper reaches.

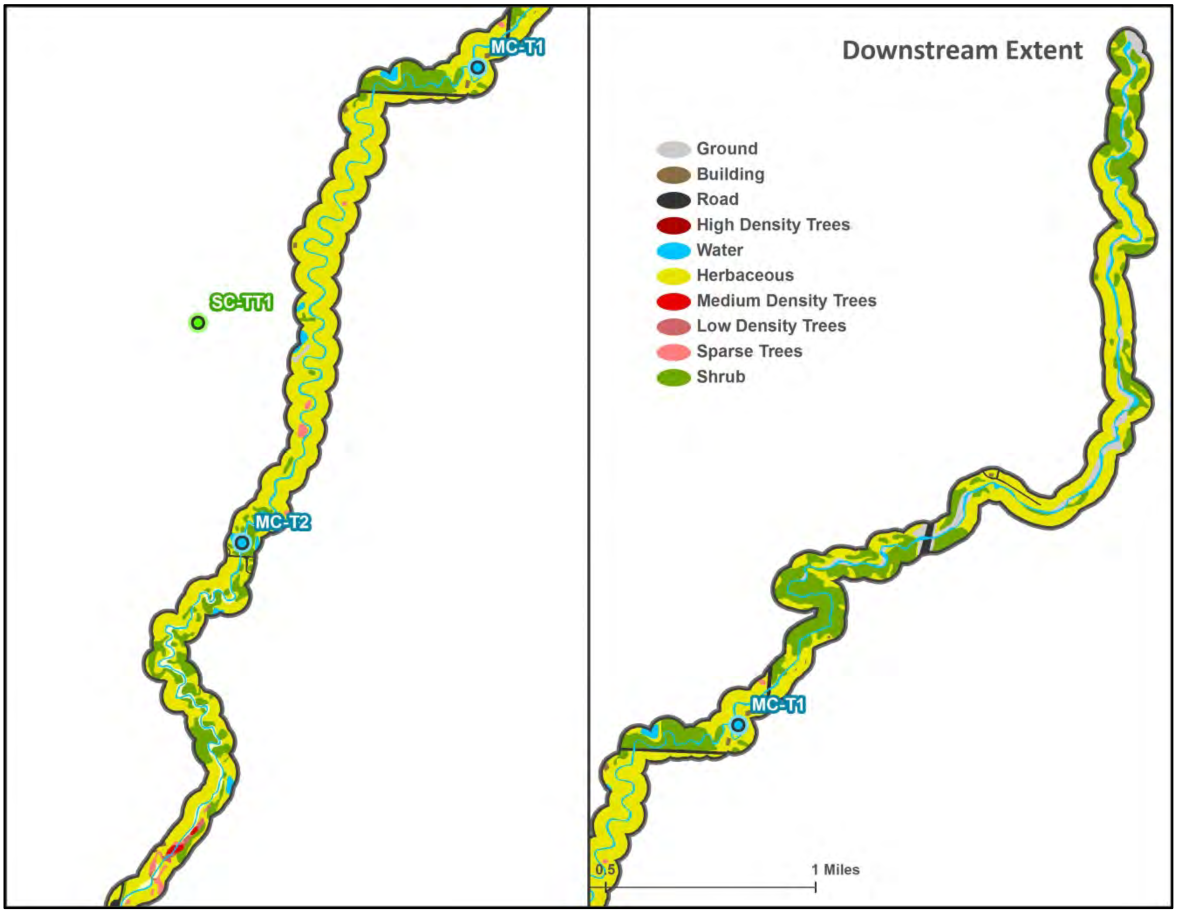


Figure A-7. Vegetation mapping example for Mill Creek in the lower reaches.

Herbaceous vegetation (47 percent) is the most common cover type along Mill Creek, followed by shrubs and trees (**Table A-2**).

Table A-2. Land cover types in the Mill Creek riparian zone

Land cover type	Area (acres)	Relative area (percent)
Buildings	0.9	0.2%
Bare ground	18.0	4.0%
Herbaceous	213.4	47.0%
Roads	5.2	1.2%
Shrub	98.3	21.7%
Sparse trees	14.8	3.2%
Low density trees	28.7	6.3%
Medium density trees	28.0	6.2%
High density trees	13.8	3.0%
Water	32.9	7.2%

A-5. Shade

Shade is one of several factors that control in-stream water temperatures. Shade is defined as the fraction of potential solar radiation that is blocked by topography and vegetation.

A-5.1. *Measured Shade*

Under contract with EPA, Tetra Tech collected shade characterization data on August 12 & 13, 2013 at six monitoring locations along Mill Creek using a Solar Pathfinder™ (**Figure A-8**). Hourly shade estimates based on the Solar Pathfinder™ measurements are presented in **Attachment A**. The data are summarized in **Table A-3**.

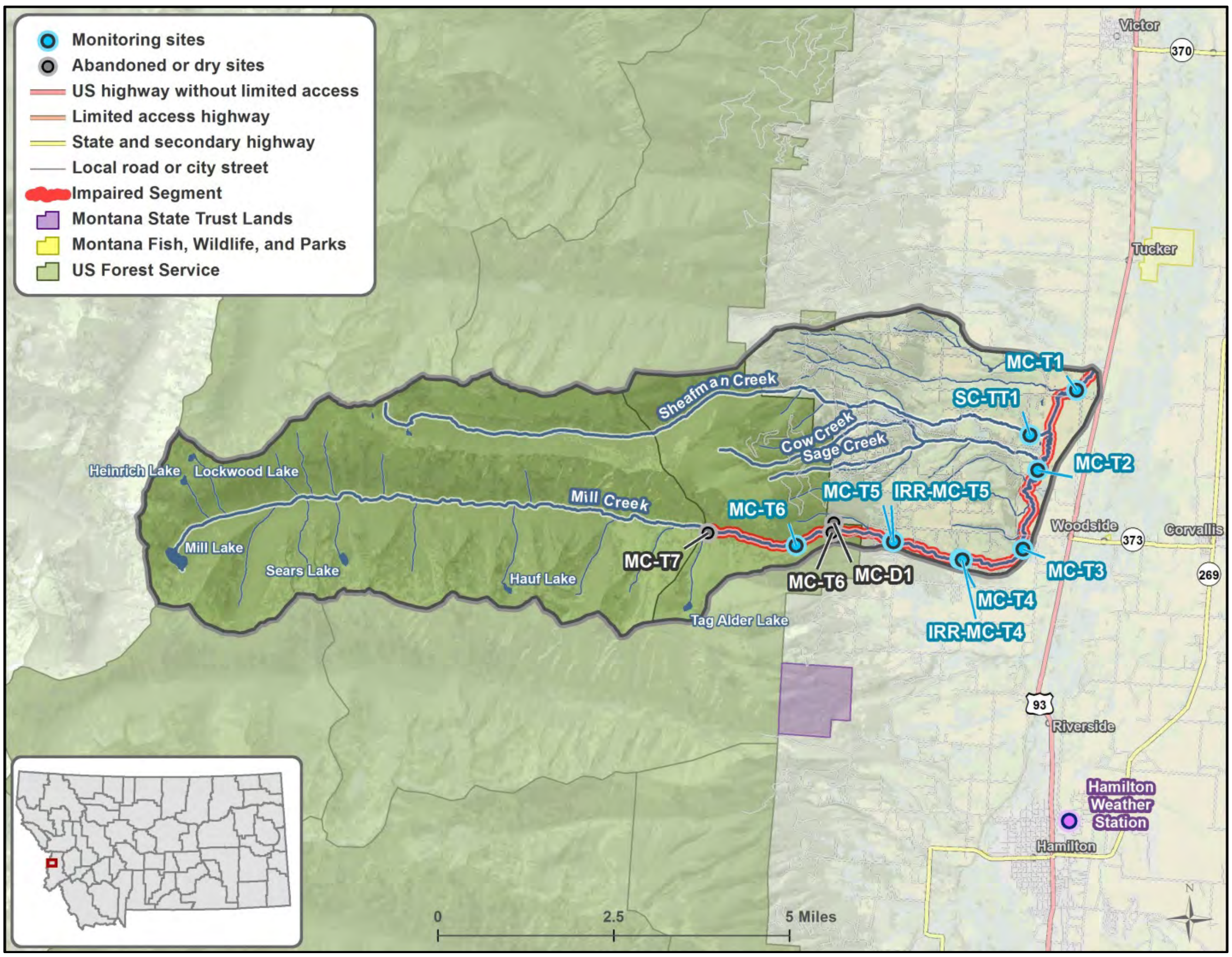


Figure A-8. EPA flow, shade, and continuous temperature monitoring locations.

Table A-3. Average shade per reach from Solar Pathfinder™ measurements

Site ID	Average daily shade (averaged across daylight hours)
MC-T6	82.8%
MC-T5	82.6%
MC-T4	61.4%
MC-T3	82.1%
MC-T2	50.6%
MC-T1	43.8%

Note: Sites are listed as headwaters to mouth from top to bottom.

A-5.2. *Shade Modeling*

An analysis of aerial imagery and field reconnaissance showed that shading along Mill Creek was highly variable. Therefore, shade was also evaluated using the spreadsheet Shadev3.0.xls. Shade version 3.0 is a riparian vegetation and topography model that computes the hourly effective shade for a single day (Washing State Department of Ecology 2008). Shade is an Excel/Visual Basic for Applications program. The model uses the latitude and longitude, day of year, aspect and gradient (the direction and slope of the stream), solar path, buffer width, canopy cover, and vegetation height to compute hourly, dawn-to-dusk shade. The model input variables include channel orientation, wetted width, bankfull width, channel incision, topography, and canopy cover. Bankfull width in the shade calculations is defined as the near-stream disturbance zone (NSDZ), which is the distance between the edge of the first vegetation zone on the left and right bank.

Available Data

The application of the Shade Model to Mill Creek relied upon the vegetation data and analysis described in **Section A-4**, aerial imagery from GoogleEarth™ (2013), tree canopy density information (MRLC 2001), and a digital elevation model (U.S. Geological Survey [USGS] 2014).

GIS Pre-Processing

TTools version 3.0 is an ArcView extension to translate spatial data into Shade Model inputs (Oregon Department of Environmental Quality 2001). TTools was used to estimate the following values: elevation, aspect, gradient, distance from the stream center to the left bank, and topographic shade. Elevation was calculated using a 10 meter (33 foot) digital elevation model (DEM) and a stream centerline file digitized from aerial imagery in GoogleEarth™. Aspect was calculated to the nearest degree using TTools with the stream centerline file.

Wetted width was estimated by digitizing both the right and left banks from aerial imagery in GoogleEarth™. TTools then calculates wetted width based on the distance between the stream centerline and the left and right banks. Topographic shade was calculated using TTools with the stream centerline file and a DEM.

Riparian Input

The Shade Model requires the description of riparian vegetation: a unique vegetation code, height, density, and overhang (OH). The vegetation input values for the Shade Model are listed in (**Table A-4**).

Table A-4. Vegetation input values for the Shade Model

Attribute	Value	Basis
Trees		
Height	19.2 meters (63 feet)	Average of field-measured values (see **Table A-1**)
Density	Variable	2006 NLCD.
Overhang	1.9 meters (6.3 feet)	Estimated as 10% of height (Stuart 2012).
Shrubs		
Height	5.3 meters (17.5 feet)	Average of field-measured values (see **Table A-1**)
Density	77%	Average of field-measured values
Overhang	0.5 meter (1.8 feet)	Estimated as 25% of height (Shumar and de Varona 2009)
Herbaceous		
Height	1 meter (3.3 feet)	Estimated
Density	100%	
Overhang	0 meters	

Shade Input

The Shade Model inputs are riparian zones, reach length, channel incision, elevation, aspect, wetted width, near-stream disturbance zone width, distance from the bank to the center of the stream, and topographic shade. Input for the riparian zone is presented above in **Table A-4**. The Shade Model requires reach lengths be an equal interval. A uniform reach length interval of 30 meters (98 feet) was used. Channel incision was estimated from an examination of field photos. Incision is the vertical drop from the bankfull edge to the water surface, and was estimated at 0.3 meter (1 foot). The remaining variables were computed as part of the GIS pre-processing described above.

Shade Model Results

The current longitudinal effective shade profile generated from the Shade Model and the Solar Pathfinder™ measurements are presented in **Figure A-9**.

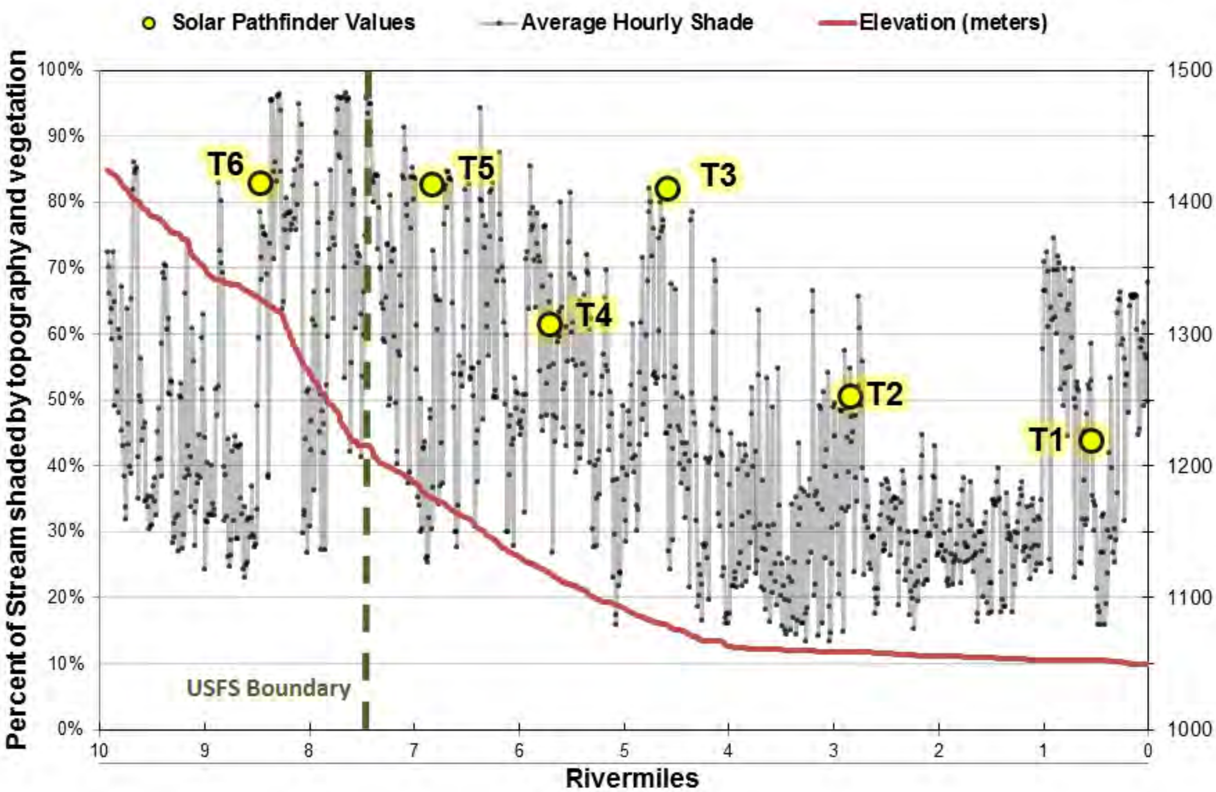


Figure A-9. Longitudinal estimates of observed and simulated effective shade along Mill Creek.

The goodness of fit for the Shade Model was summarized using the mean error (ME), average absolute mean error (AME), and root mean square error (RMSE) as a measure of the deviation of model-predicted shade values from the measured values. These model performance measures were calculated as follows:

$$ME = \frac{1}{N}\sum_{n=1}^{n} P_n - O_n$$

$$AME = \frac{1}{N}\sum_{n=1}^{n} |P_n - O_n|$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{n=1}^{n}(P_n - O_n)^2}$$

where

P = model predicted values
O = observed values
n = number of samples

Model error statistics are provided in **Table A-5** and suggest a good fit between observed and predicted average effective shade values. The average absolute mean error is 5 percent. (i.e., the average error from the Shade Model output and Solar Pathfinder™ measurements was 5 percent daily average shade; see **Table A-5**).

Table A-5. Shade model error statistics

Error Statistic	Formula	Result	Units
Mean Error (ME)	$(1/N)*\Sigma(P_n-O_n)$	-3%	percent of percent shade
Average Absolute Mean Error (AME)	$(1/N)*\Sigma\|(P_n-O_n)\|$	5%	percent shade
Root Mean Square Error (RMSE)	$[(1/N)*\Sigma(P_n-O_n)^2]^{1/2}$	6%	percent of percent shade

A-6. Stream Temperatures

In 2013, Tetra Tech collected continuous temperature data at six locations in Mill Creek and at one tributary. Data loggers recorded temperatures every one-half hour for approximately two months between June 26-27 and September 9, 2013. In 2007, Montana DEQ collected continuous temperature data at two locations on Mill Creek.

Instantaneous temperatures were also monitored by Tetra Tech in June, August, and September 2013(**Table A-6**). Additionally, Montana DEQ recorded an instantaneous temperature of 76.5° F on July 12, 2007, at the C05MILLC01 station.

Table A-6. EPA instantaneous water temperature measurements (°F), summer 2013

Date	MC-T1	SC-TT1	MC-T2	MC-T3	MC-T4	MC-T5	MC-T6
June 26, 2013	56.4	54.4	55.9	54.2	--	---	-
June 27, 2013	--	--	--	--	50.3	50.7	51.2
August 13, 2013[a]	--	Dry	--	--	--	--	--
September 9, 2013	66.7	Dry	59.5	66.0	57.9	62.3	59.5

Notes
Temperatures were originally reported in degrees Celsius and were converted to degrees Fahrenheit as displayed in this table.
a. Temperature data rejected due to quality control issues with the temperature probe calibration.

A-7. Hydrology

No active USGS continuously recording gages are located on Mill Creek. EPA collected instantaneous flow measurements in 2013, during temperature data logger deployment and retrieval, as well as during mid-season site visit (**Table A-7**). DEQ monitored flow on July 12, 2007 at site C05MILL01 (9.8 cfs). Locations of the flow measurements are shown in **Figure A-10**. A portion of Mill Creek, approximately 0.25 miles downstream from logger MC-T3 was observed to be dry during an August 12, 2013 site reconnaissance visit. Flow resumed upstream from logger MC-T2.

Table A-7: EPA instantaneous flow measurements (cfs) on Mill Creek in support of modeling

Date	FLUME @ MC –T6A	FLUME @ MC –T6B	MC –T6	MC –T5	MC –T4	MC –T3	SC –TT1 [a]	MC-T2	MC-T1
June 26-27, 2013	--	--	88.4	75.28	47.89	43.79	10.47	50.74	69.50
August 12-13, 2013	4.13	2.68	16.30	3.09	2.28	0.22	0	5.35	2.31
September 9, 2013	--	--	9.83	1.60	1.48	0.11	0	3.66	1.94

Note: a. Site is on Sheafman Creek that is a tributary of Mill Creek.

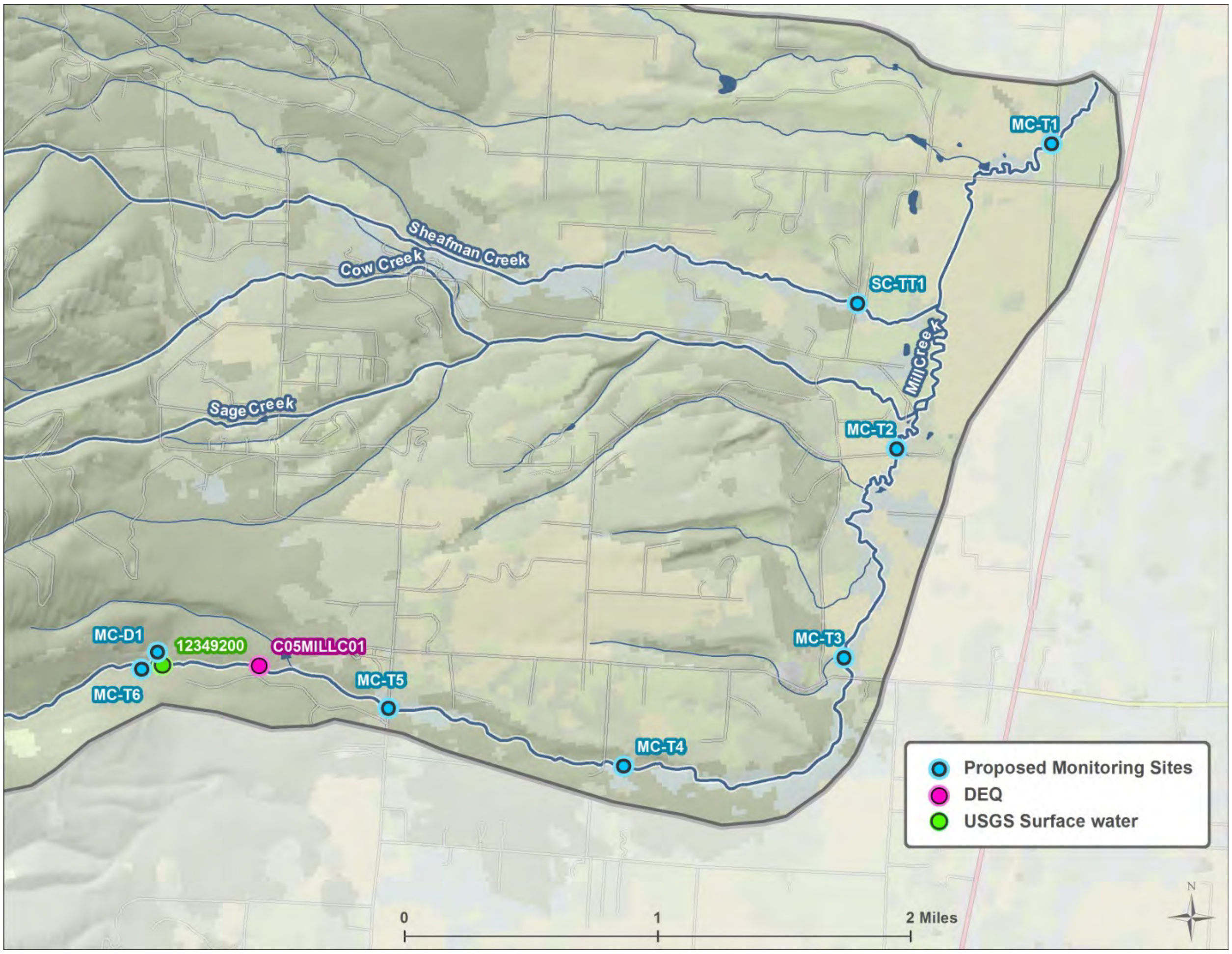
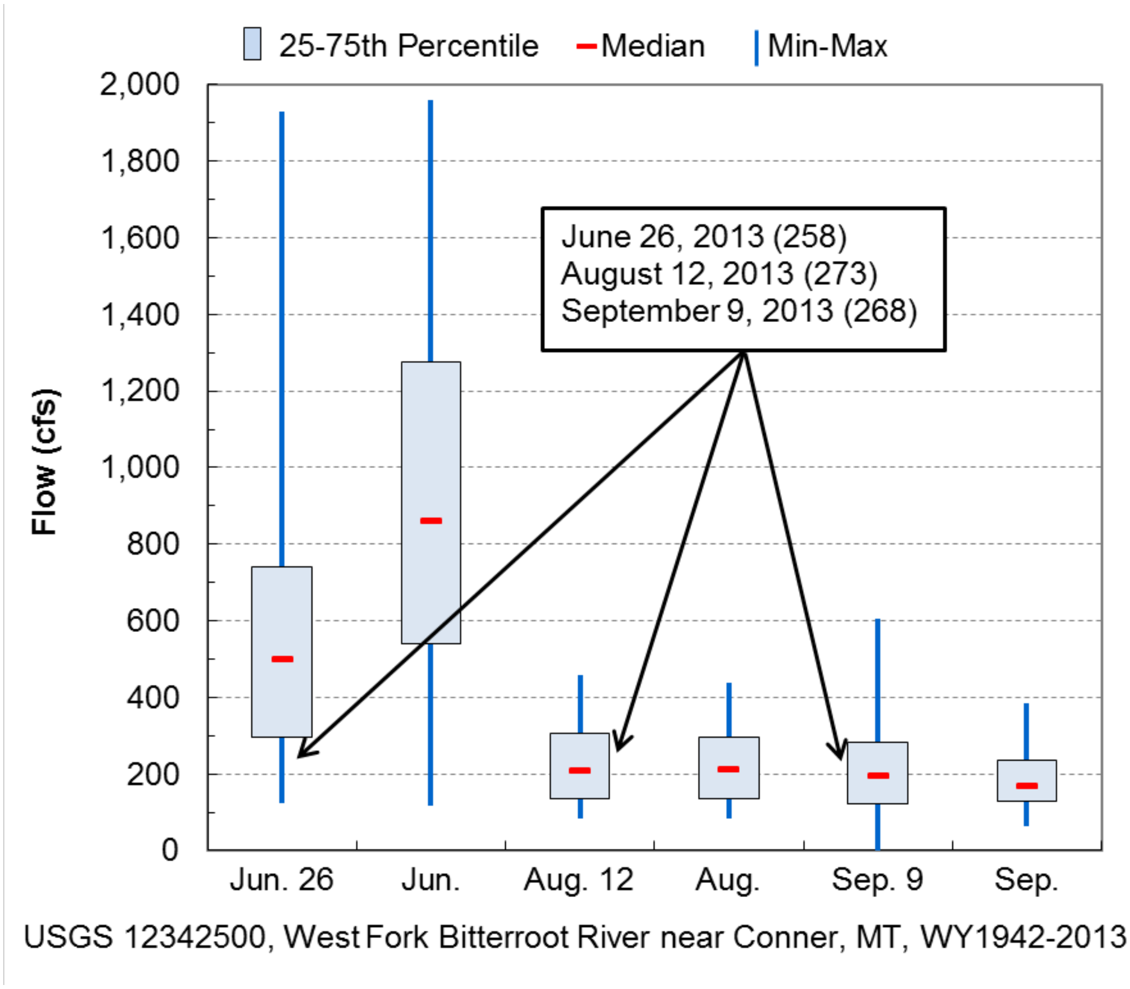


Figure A-10. Flow monitoring locations in the Mill Creek watershed.

Continuous flow data monitored on the West Fork Bitterroot River at USGS gage 12342500 were evaluated with instantaneous discharge data from Mill Creek to assess the hydrologic conditions of Mill Creek during the summer of 2013. USGS gage 12342500 was used as a surrogate to represent regional hydrologic conditions. Statistics were calculated for the average daily flows (per year) for the month of June and for June 26th from water years 1941 through 2013 at the gage (**Figure A-11**).

The flow at gage 12353650 on June 26, 2013 (the calibration date for the QUAL2K model) was 258 cfs, which is near the 25th percentile of flows on June 26th across the period of record. At gage 12353650, flow on June 26 was similar to flows on August 12 and September 9 (**Figure A-11**).



Note: "June" represents the daily average flow for the month of June per year (i.e., the average of 30 daily average flows). Similarly, August and September represent the daily average flow for the moths of August and September per year.

Figure A-11. Average daily flows for the months of June, August, and September and for June 26, 2013, August 12, 2013, and September 9, 2013 at USGS gage 12342500(West Fork Bitterroot River).

A-8. Flow Modification

There are 13 ditches actively withdrawing water from Mill Creek for irrigation purposes[1]. Of these, nine ditches were withdrawing water during the study period (**Figure A-12**). It is estimated that between approximately 5 and 24 cfs are withdrawn from Mill Creek during the study period (**Table A-8**).

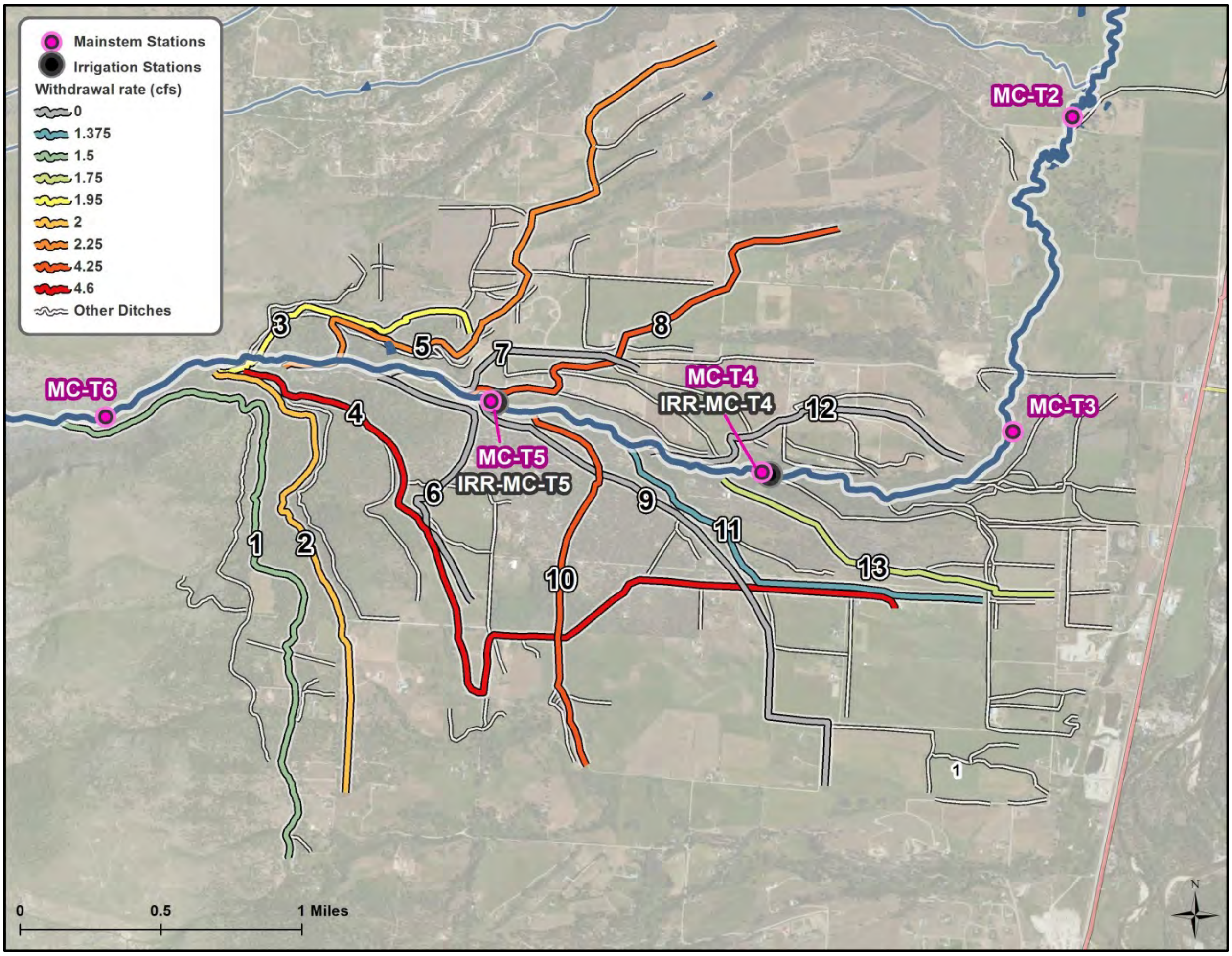


Figure A-12. Ditches actively withdrawing water from Mill Creek on June 26 and 27, 2013.

[1] According to Jordan Tollefson (TMDL Planner, DEQ), based on personal communications with Sandy Schlotterbeck and David Allen of the Mill Creek Irrigation District on February 5th, 10th, and 13th, 2014.

Table A-8. Summary of irrigation diversions from Mill Creek

Ditch ID	Daily flow rate (cfs)			
	June 26/27	August 12	August 13	September 9
1	1.50	1.25	1.25	0
2	2.00	0	2.25	0
3	1.95	0	2.60	0
4	4.60	3.76	4.08	1.00
5	2.25	2.40	2.43	1.00
6	--	--	--	--
7	--	--	--	--
8	4.25	4.08	3.60	2.25
9	--	--	--	--
10	4.25	0	0	0
11	1.38	0.75	0.75	0.75
12	--	--	--	--
13	1.75	0.43	0.43	0
Total Withdrawal	***23.93***	***12.66***	***17.38***	***5.00***

Note: Values originally provided in Miner's Inches and converted to cfs.

A-9. Point Sources

There are no permitted discharges in the Mill Creek watershed.

Three abandoned mines are present in the Mill Creek watershed, all situated near the U.S. Forest Service boundary. Mill Creek Mine, a former titanium, iron, thorium, and zirconium producer, was near Mill Creek. Ore Finder Group Mine, an expired prospect mine, was near Fred Burr Creek. Sheafman Creek Mine, another titanium, iron, thorium, and zirconium producer, was near Sheafman Creek.

The mines are not expected to have an influence on stream temperature and are not considered further.

A-10. References

DEQ (Montana Department of Environmental Quality). 2012. Water Quality Assessment Database. Montana Department of Environmental Quality, Clean Water Act Information Center. <http://cwaic.mt.gov/query.aspx>. Accessed March 16, 2012.

GoogleEarth™ 2013. Aerial imagery of Mill Creek and surrounding area. dated November 20, 2011 <http://www.google.com/earth/index.html>. Accessed May 29, 2013.

MRLC (Multi-Resolution Land Characteristics Consortium). 2001. *National Land Cover Dataset 2001*. <http://www.mrlc.gov/nlcd2006.php>. Accessed June 28, 2012.

MRLC (Multi-Resolution Land Characteristics Consortium). 2006. *National Land Cover Dataset 2006*. <http://www.mrlc.gov/nlcd2006.php>. Accessed June 28, 2012.

National Climatic Data Center. 2013. *Monthly Summaries GHCND.* <http://www.ncdc.noaa.gov/land-based-station-data/find-station>. Accessed June 18, 2013.

Natural Resources Conservation Service. 2003. *Irrigation Water Requirements.* < <http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/irrigation/?cid=stelprdb1044890>. Accessed February 6, 2013.

NRIS (Natural Resources Information System). 2012. *GIS Data List.* <http://nris.mt.gov/gis/gisdatalib/gisDataList.aspx>. Accessed June 28, 2012.

Oregon Department of Environmental Quality. 2001. TTools 3.0 Users Manual. Oregon Department of Environmental Quality.

Oregon Department of Environmental Quality. 2009. TTools version 7.5.6 (TTools 756.mxd in TTools756.zip) in *Water Quality: Total Maximum Daily Loads (TMDLs) Program: Analysis Tools and Modeling Review* at <http://www.deq.state.or.us/wq/tmdls/tools.htm>. Downloaded July 1, 2011.

Poole, G.C., Risley, J. and M. Hicks. 2001. Issue Paper 3 – Spatial and Temporal Patterns of Stream Temperature (Revised). United States Environmental Protection Agency. EPA-910-D-01-003.

Shumar, M. and J. de Varona. 2009. The Potential Natural Vegetation (PNV) Temperature Total Maximum Daily Load (TMDL) Procedures Manual. Idaho Department of Environmental Quality. State Technical Services Office. Boise, ID.

Stuart, T. 2012. Asotin Creek Temperature Straight-to-Implementation Vegetation Study. Washington State Department of Ecology. Eastern Regional Office. Spokane, WA.

U.S. Forest Service. 2008. *Fire History in the Bitterroot National Forest.* <http://www.fs.usda.gov/detailfull/bitterroot/landmanagement/gis/?cid=stelprdb5157563&width=full>. Accessed February 4, 2014.

USGS (United States Geological Survey). 2014. *National Elevation Dataset*. <http://ned.usgs.gov>. Accessed January 20, 2014.

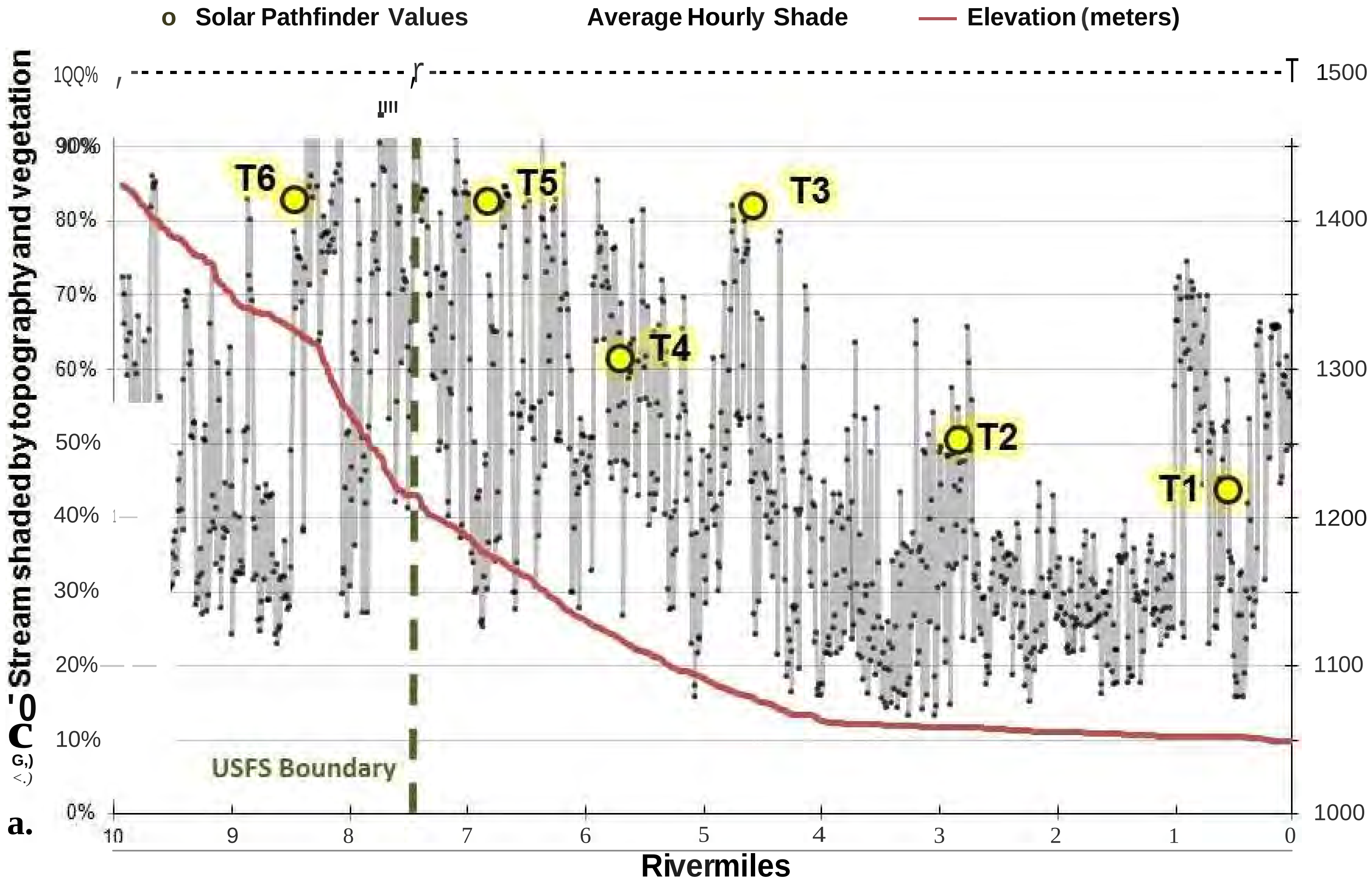
Washington State Department of Ecology. 2007. *Shade* (shade_ver31b02.xls in shade.zip*)* in *Models for Total Maximum Daily Load Studies* at <http://www.ecy.wa.gov/programs/eap/models.html>. Downloaded November 29, 2011.

Washington State Department of Ecology. 2008. *tTools for ArcGIS (*tTools for ArcGIS 9.x (Build 7.5.3).mxd in tTools_for_ArcGIS.zip) in *Models for Total Maximum Daily Load Studies* at <http://www.ecy.wa.gov/programs/eap/models.html>. Downloaded November 29, 2011.

Western Regoinal Climate Center. 2013. *Monthly Summary Time Series.* <http://www.raws.dri.edu/cgi-bin/rawMAIN.pl?mtMSMI>. Accessed February 12, 2014.

Appendix B.

Vegetation and Shade Analysis for Scenario Development



a.

This reach (RM 0 to "4.S) is relatively low gradient and flows through the Bitterroot Valley bottom. Irrigated agriculture mixed with low density residential land uses predominant. Much of this reach is not meeting its shade potential due to encroachment by these land uses ("yellow" area downstream of MC-T2 shown below). However, based on site reconnaissance in 2013, the vegetation at Site MC-T2 is at potential and will be used as a reference condition for this reach. Vegetation in the vicinity of MC-T2 consists of a SO to 100 foot buffer of shrubs (see below) and average daily effective shade is approximately SO%. In the improved shade scenario, areas less than SO% shade will be increased to that level. Areas already exceeding SO% shade will not be modified.

From RM 10 down to approximately RM 7.S, Mill Creek flows through the Bitterroot National Forest. In spite of the fact that a fire occurred in the area in 2000, vegetation in this area is considered at potential.

From RM 7.S down to approximately RM 4.S, Mill Creek flows through the Bitterroot National Forest. In spite of the fact that a fire occurred in the area in 2000, vegetation in this area is considered at potential. Between RM 9.S and RM 6.S, Mill Creek flows through an area transitional from the mountains (dominated by coniferous forest) down to the valley. Much of this reach is dominated by mixed coniferous/deciduous forest with some encroachment by residential and agricultural land uses. Site MC-T3 (a forested site dominated by mixed coniferous/deciduous vegetation) was considered at potential based on site reconnaissance and will be used as a reference condition for this reach in the improved shade scenario.